Property Flood Resilience – Scottish Baseline Study

Angus Pettit and Heather Kerr, JBA Consulting
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1 Executive summary

1.1 Aims and approach

This research provides an up-to-date baseline assessment of the potential for Property Flood Resilience (PFR) across Scotland. The findings will support the Scottish Government and its partners in the Property Flood Resilience Delivery Group deliver the Living with Flooding: action plan[1]. This plan, published in November 2019, outlines steps to promote PFR for delivering property flood resilience in Scotland, including building a better evidence base.

As flood risk is increasing with climate change, it is imperative that communities at risk are as equipped as possible to deal with flooding. Once a best estimate of the potential for PFR has been estimated, action can be taken to further understand the reasons for PFR uptake, or lack thereof, and the mechanisms to encourage uptake and implement such measures.

The term PFR covers both resistance and resilience measures. These are defined as follows:

- Resistance measures are installed to exclude floodwater from a property entirely, for example, through door guards, non-return valves and airbrick covers. Resistance measures could cover garden walls or structures beyond the property, as well as the property itself.
- Resilience measures are designed to limit the damage caused by floodwater which has already entered a building. These measures include modification/ rearrangement of existing features such as raising electrical sockets, waterproof plaster and moving valuable goods to upper floors. The aim of resilience is not to prevent floodwater from entering a property, but to limit the recovery time post-flood.

[1] Scottish Government. Living with Flooding: action plan https://www.gov.scot/publications/living-flooding-action-plan-delivering-property-flood-resilience-scotland/

This research has analysed SEPA flood-map data and qualitative surveys to determine the following:

1. The flood risk circumstances whereby properties would benefit from PFR;
2. The estimated number of properties and businesses at risk from flooding in each local authority area which could benefit from PFR today and in the future, allowing for climate change projections; and
3. The uptake of PFR measures in Scotland in 2019, including how and when measures were installed.

1.2 Key findings

Quantitative analysis was used to identify the number of residential and non-residential properties that could benefit, both at a national scale and a regional scale (local authorities):

- Potentially around 81,000 properties may benefit from the uptake of some kind of PFR measure. This is around one third of all properties at risk of flooding in Scotland from any source.
- All of the above properties could benefit from some form of manual resistance measures (such as door and window guards, airbrick covers). Of these, 64,000 could benefit from automatic measures (such as sumps and pumps, non-return valves, automatic airbricks).
- Of the 81,000 properties above, 40,000 may also benefit from resilience measures.
- Areas where surface water flooding is usually less than 0.6m in depth will benefit the most from PFR measures.
- Glasgow and other cities, such as Edinburgh and Aberdeen, have the potential to benefit most from PFR measures that mitigate surface water flooding. Falkirk and more rural communities, such as Highland and Argyll and Bute, could benefit from PFR to protect against coastal flooding, and areas, including the Scottish Borders, Dumfries and Galloway and Glasgow, will benefit most from fluvial flood protection.
- The number of properties that could benefit from PFR is expected to rise by 25,000 to 43,000 (30-70%) by the 2080s due to climate change.

A questionnaire was issued to local authorities and flood groups to assess the uptake of PFR measures across Scotland. The main conclusions are:

- An estimated 1,400-1,500 properties are protected by PFR across Scotland.
- The number of properties with PFR measures has increased by at least 300 since 2014, with the majority installed by local authorities.
- Several local authorities have PFR subsidy schemes, allowing property owners cheaper access to measures. Two subsidy schemes account for the majority of properties benefitting from PFR in Scotland (Dumfries and Galloway and Scottish Borders), with smaller numbers delivered by local flood groups and individuals.
- A number of key best practice aspects to the installation and testing of PFR measures (post-installation surveys, guidance and maintenance) that are not being followed rigorously in Scotland and which may impact whether PFR measures are successfully deployed.

The findings suggest that there is a relatively low level of uptake of PFR in Scotland. Local authorities are currently giving the greatest assistance in terms of PFR provision and encouraging homeowners to uptake measures. However, there is significant potential for wider uptake of PFR to contribute to flood risk management and climate resilience in Scotland.

Therefore, while local authorities appear to have led the way in terms of contributing to PFR uptake, it should be remembered that homeowners are responsible for their properties, and independent uptake by these groups needs to be encouraged and facilitated further.

Furthermore, as the number of properties at risk of flooding in Scotland increases with climate change, this study shows that PFR approaches can assist as a resilience measure, particularly for those properties flooding most frequently. Uptake needs to increase significantly over the short to medium term to ensure that Scotland employs the range of flood management measures best able to reduce the impact of flood risk, both current and in the future.

The analysis suggests uptake of PFR in Scotland would need to increase to 400-600 properties per annum just to keep up with the projected increased impact on flooding from climate change, even without reducing current risks. This highlights both the significant role that PFR can play in managing the impacts of climate change on flood risk, but also the significant challenge in increasing uptake.

This baseline report provides the first step in understanding the potential for PFR in Scotland. The next stage of the 'Living with Flooding: action plan', is to consider possible reasons for the poor uptake of PFR and approaches to encourage uptake more widely.

Contents

2 Introduction

2.1 Project aims

This study aims to provide a baseline assessment of the potential for PFR across Scotland. Despite research into aspects of PFR in Scotland, an up-to-date assessment of the current level of PFR uptake across the nation is needed, along with an assessment of the number of properties that may benefit, and crucially, where they are located.

The specific research objectives are as follows:

- Identify the flood risk circumstances whereby properties would benefit from PFR.
- Estimate how many properties and businesses at risk from flooding in each local authority area might benefit most from PFR today and in the future.
- Assess the uptake of PFR measures in Scotland, including how and when measures were installed.

This research aims to update the analysis undertaken previously by the Scottish Government in 2013/14[2] using more up-to-date flood risk data supplied by the Scottish Environment Protection Agency (SEPA) from its National Flood Risk Assessment (NFRA) 2018 analysis.

The research follows on from the Scottish Government's 'Living with Flooding Action Plan'[3]. The Action Plan identified that whilst funding of flood protection schemes in Scotland will protect many properties, a significant number will not. Other flood management measures need to be encouraged; in particular those measures that can make individual properties more resilient to flooding.

The action plan has a number of key objectives:

- Building a better evidence base – through research and case studies determine the uptake of, the successes, the obstacles to uptake and cost benefits of PFR;
- Influencing policy and providing clear guidance – provide clear, consistent information and guidance on PFR used by industry and property owners or occupiers; and
- Recognising and supporting positive change – encourage more PFR measures during renovations or re-instatement by promoting the economic and social benefits of flood resilience.

This project aims to support the first of these three key objectives and provide a baseline to measure progress.

2.2 Resistance vs resilience

Property Flood Resilience (PFR) measures can significantly reduce the damage and disruption caused by flood water entering a property. PFR measures can help make a property more resilient to the physical impacts of flooding, and so in turn reduce the emotional impact to a person caused by flooding.

Previously, PFR was more commonly known in government guidance as Property Level Protection (PLP), but this terminology has now shifted from protection to resilience to

2 Scottish Government. Assessing the flood risk management benefits of property level protection. Available at: https://www.gov.scot/publications/managing-flood-risk-research/ [Accessed 9 June 2020].

3 https://www.gov.scot/binaries/content/documents/govscot/publications/strategy-plan/2019/11/living-flooding-action-plan-delivering-property-flood-resilience-scotland/documents/living-flooding-action-plan-delivering-property-flood-resilience-scotland/living-flooding-action-plan-delivering-property-flood-resilience-scotland/govscot%3Adocument/living-flooding-action-plan-delivering-property-flood-resilience-scotland.pdf

accommodate measures involving resilient property floors, walls and interiors to reduce the impact of floodwater entering a property.

PFR measures are often broken down into 'resistance' and 'resilience' measures:

1) Resistance measures aim to keep floodwater outside the property. Measures include door guards, airbrick covers, waterproofing of walls, non-return valves and a sump pump, for example. Resistance measures may be ‘automatic’ or ‘manual’. Automatic resistance measures do not require manual deployment, whereas manual resistance measures require fitting by the homeowner or tenant before a flood event. As a result, manual measures are often more beneficial in areas with flood warnings and strong communities, as this allows the property owner time to deploy the measure.

2) Resilience measures limit damage caused as a result of water entering a property. This includes measures such as waterproof plaster, raised electric sockets, solid concrete floors and tiled floor coverings. These measures do not prevent water from inundating a property, but reduce flood damage and shorten the recovery time after a flood.

This report considers both resistance and resilience measures, and the uptake of these across Scotland in the form of both quantitative and qualitative analyses, detailed below in Section 2.3.

2.3 Approach

A twofold analysis approach was taken for the study:

- Quantitative analysis of the properties at risk from flooding in each local authority and the applicability of resistance (manual/automatic) and resilience measures. This is detailed in Sections 4 and 5, with the technical areas of analysis detailed in Annex A. In order to determine the criteria for this quantitative analysis a thorough review of the parameters that apply is detailed in Section 3.
- Qualitative data gathering from stakeholders in the form of the online PFR survey. **Section 6** and **Section 7** cover this analysis. The full questionnaire is detailed in Annex C.

The criteria assessment in Section 3 sets the criteria for which properties may benefit from PFR. The purpose of the quantitative analysis was to assess the number of properties at risk from flooding both at present and for future climate change scenarios. The number of properties at risk of flooding has been identified in each local authority as well as the number of properties potentially benefitting from PFR by each flood source. Climate change analysis has yielded values for the number of properties that may benefit from PFR measures in the future.

We have utilised SEPA’s flood receptor database (National Flood Receptor Assessment) (SEPA, 2018a) that holds information on every property in Scotland alongside flood depths resulting from a range of return periods. This represents the most up-to-date information with respect to property data and flood mapping.

The qualitative analysis aims to determine the current PFR uptake and number of properties currently benefitting from PFR in Scotland. This included type of measure, when measures were installed and the performance of these measures. The questionnaire was distributed to local authorities and local flood groups. Data was also collected on PFR maintenance and who installed the measures.

This report provides a technical analysis of the properties at risk of flooding from fluvial, surface water and coastal sources, the potential number of properties that could benefit from PFR, and the results from the stakeholder survey.

3 Criteria Assessment

3.1 Introduction

JBA has reviewed research surrounding circumstances whereby PFR would be considered effective. Research has shown that flood depth and frequency are the most significant criteria. The height of a PFR measure is typically restricted for PFR measures to a retained water depth that when surpassed, a building's capacity to act as a retaining wall is exceeded. This is the case for resistance measures but not resilience measures.

Flood frequency is relevant as, when a property floods frequently, it is typically more cost effective to install PFR measures. There is also a clear inconsistency between the cost effectiveness of resistance and resilience measures. Several reports have considered the importance of flood depth and frequency on the selection of PFR measures including JBA (2012), Royal Haskoning (2012), Joseph (2014), JBA (2014) and Flood Re (2018).

Up to a depth of 0.6m, PFR measures are generally deemed to be effective. This is because above this depth, the structural integrity of a building can become compromised. However, there is a lack of research on the influence of property construction types. An upper limit does not tend to apply to resilience measures although there is often a practical constraint in terms of, for example, how high white goods can be raised. British Standards Institution guidance (BSI, 2015) makes recommendations concerning flood depths and water exclusion. It is recommended that water should be excluded up to 0.3m, partially excluded up to 0.6m and allowed to breach above 0.6m (Flood Re, 2018). Royal Haskoning (2012) explore raising resistance measures to 0.9m, although Joseph (2014), JBA (2012; 2014) and Flood Re (2018) all suggest that this number should remain at 0.6m.

3.2 Flood and property circumstances influencing PFR

This report compiles a review of research into the circumstances where PFR would normally be considered effective including flood depth and frequency. These criteria was used to select key values for this study and inform a set of rules which applied to the receptor database to generate an output of properties that would most benefit from PFR.

The key aspects of this review comprise the following:

- Flood depth. The height of PFR measures is typically restricted to a depth of water above which the building's capacity to act as a retaining wall is exceeded.
- Flood frequency and cost effectiveness. Research has shown that PFR measures are most cost effective for properties that flood frequently. Research has also shown that there is a clear discrepancy in cost effectiveness between resistant and resilience measures.
- Groundwater flooding. Properties at risk of rising water tables may impact properties which have basements and can seep into property with suspended floors.
- Speed of onset. PFR measures which require manual deployment need enough time to be deployed. Communities in areas of rapid onset may not therefore be applicable to certain types of PFR approaches or require well developed emergency plans both at the community and individual level.
- Velocity of flooding. Properties in locations of high flow velocities may not be suited to PFR due to the risk of structural failure.
- Duration of flooding. PFR measures may be less effective for long duration floods.

- Property type. Research suggests that bungalow and detached properties will benefit most from PFR. Furthermore, problems can arise on some terraced properties where neighbours do not also implement PFR.
- Historic status. Bespoke measures are developing for historic or listed buildings, but these may have higher costs making PFR less economically viable.
- Number of occupants. This can affect the choice of PFR measures, especially for lone homeowners.
- Non-standard construction. Non-standard construction, poor quality brick, porous material or poorly maintained structures can influence the choice, cost effectiveness and uptake of PFR measures.
- Presence of flood warning. Flood warning may be needed for manual resistance measures.
- Commercial buildings. Non-residential properties may not be suitable for PFR measures or the costs of implementing PFR may be significantly more (although these may be offset by higher benefits).
- Clustering of properties. Properties located in a community at risk may be more likely to be identified for PFR uptake than isolated ones. It may also be more efficient to deliver and manage PFR to properties located in a community.
- Upper floor flats. Upper floor flats will not require PFR unless they have ground floor access or shared services at risk.

Each of the above is discussed further in Annex A.

3.3 Summary of applied criteria

GIS analysis to identify properties which could potentially benefit from PFR was conducted using a set of rules outlined below.

Table 1: Rules and criteria applied during analysis

Factor	Rules and criteria
Depth	All properties (except where exclusions from other criteria apply) identified as being at risk were counted to determine those benefitting most from resilience PFR approaches. Properties with depths less than 0.6m were counted to determine those benefitting most from resistance PFR approaches.
Frequency	Resistance (manual) were only applied to properties at risk at the 40-50 year return periods. Resistance (automatic) were only applied to properties at risk at the 20-25 year return periods. Resilience was only applied to properties at risk at the 5-10 year return periods.
Commercial buildings	Only retail, office and public buildings were included and any properties with areas greater than the FHRC MCM 'indicative area' were excluded.
Upper floor flats	Upper floor flats were excluded from the analysis.
Groundwater	Properties with known basement were excluded.

The frequency criteria is not a precise science as cost effectiveness of measures will vary due to a number of factors. However, for simplicity we have applied it to the following key flood events modelled by SEPA:

- Resistance (manual) – aligned with SEPA's 50-year return period (2% Annual Probability (AP) flood).

- Resistance (automatic) – aligned most with SEPA's 30-year return period (3.33% AP flood). We did not have 20- or 25-year return period data available to us.
- Resilience – aligned with SEPA's 10-year return period (10% AP flood). SEPA have not modelled a 5-year return period.

4 Properties benefitting from PFR: Quantitative analysis

4.1 Introduction

The purpose of this analysis is to provide a baseline assessment against which the future uptake of PFR can be measured. As discussed in Section 2, PFR can be split into resistance and resilience measures, both of which come under the umbrella of Property Flood Resilience. As part of the national-scale assessment of PFR uptake, a series of Geographical Information System (GIS) analysis methods have been employed to extract areas relevant for the study. These methods include data exclusion and calculations to produce final outputs for resistance (manual), resistance (automatic) and resilience measures.

4.2 Methodology

The key criteria used for analysis were depth and flood frequency; properties that flood frequently were considered to be most applicable for PFR. As data was provided separately for coastal, fluvial and surface water flooding, different outputs for residential and non-residential properties were produced for each scenario. The methodology steps taken were as follows:

1) Properties not flooding at the 200 year plus climate change (+CC) flood event were stripped out of the analysis to make it more manageable.
2) The analysis also excluded properties with several parameters not deemed applicable to PFR, including properties with basements, upper floor flats and properties with floor areas greater than the Multi-Coloured Manual (MCM) indicative area (non-residential only).
3) We then broke the data down into fluvial, coastal and surface water counts for each Scottish local authority. By filtering the data by depth, we were able to determine how many properties may benefit from PFR. Resilience measures tend to perform most effectively on properties at risk up to the 10-year return period, resistance (automatic) up to the 30 year return period and resistance (manual) up to the 50 year return period.

The methodology outlined above is illustrated in Figure 4.1.

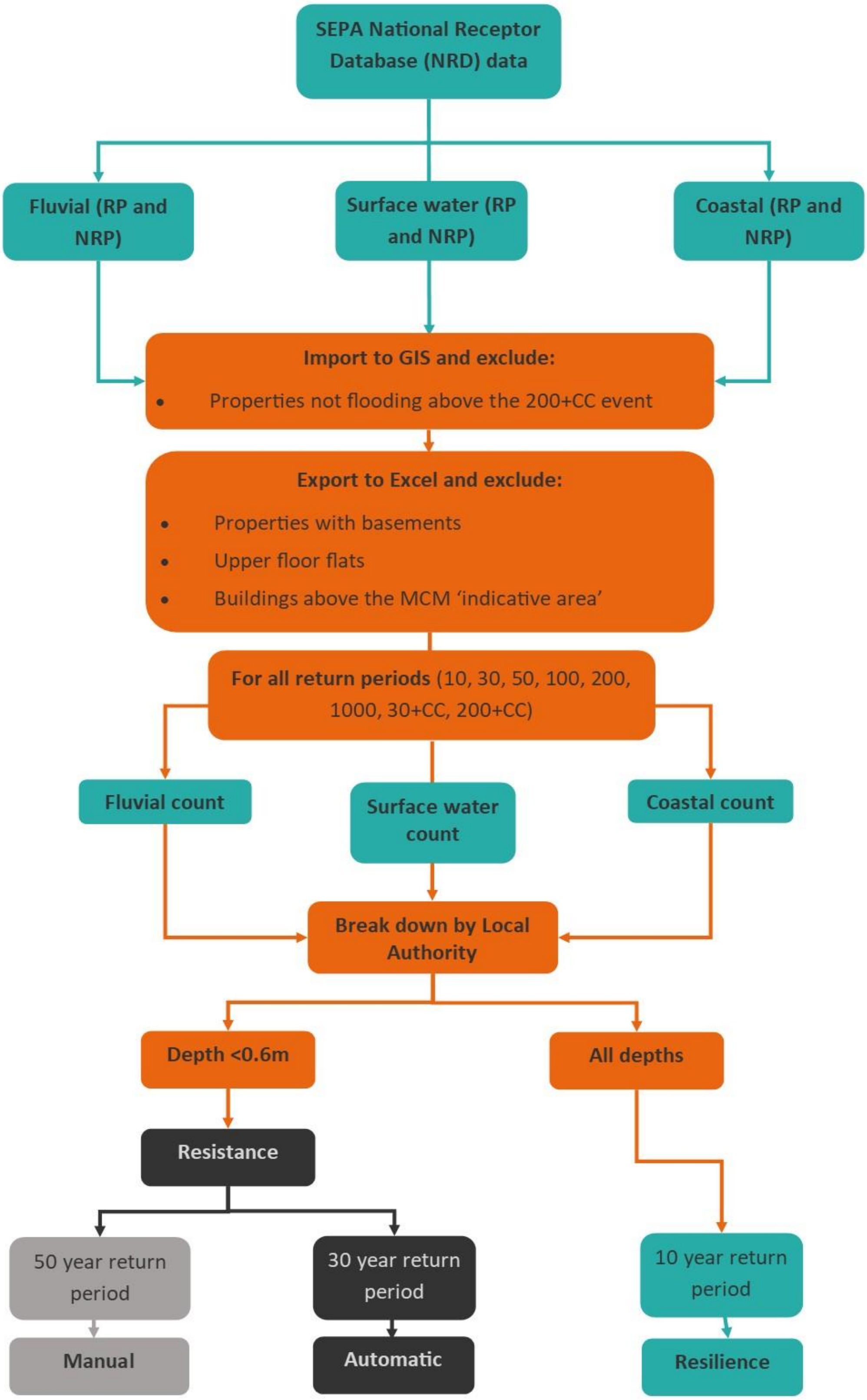

Figure 4-1: Flowchart of quantitative methodology undertaken during property counts

5 Results of baseline assessment

Analysis of properties benefitting has been carried out based on the criteria outlined in Section 3, and the methods employed in Section 4.

5.1 Key findings

Results show that:

- 319,000 properties are at risk of flooding from any source for a 200-year return period event. This total includes some double counting (i.e. properties flooded from multiple sources). Currently, the national figure from the NFRA is 284,000 at the 200-year return period (non-double counted). We performed a check to identify our non-double counted value. This sits at 270,000 – lower than the NFRA value. This is attributed to the exclusion of certain criteria during analysis.
- Based on the criteria used in this research the total number of properties that could benefit from some type of PFR is 81,000. All these properties would benefit from manual resistance measures. Of the 81,000 we estimate that 64,000 properties would benefit from automatic resistance measures and 40,000 from resilience measures. For this reason these counts should not be added together. The choice of measure will be influenced by a range of factors including cost, flood source, availability of flood warning, property type and resident, available financial and practical support, and the logistics of the work.
- Most local authorities could potentially benefit from PFR on over 30-40% of properties. There is therefore a large potential for the implementation of PFR measures across Scotland. However, in the largest cities with the greatest flood risk, while the number of properties that could benefit is higher; as a percentage of overall properties at risk it is lower. Further research is needed to ascertain the reason for this.
- Some of the larger cities with the greatest risk, such as Glasgow, Edinburgh and Dundee, have the highest number of properties that could benefit from PFR measures to mitigate surface water flooding. Local authorities such as Falkirk, Highland and Argyll and Bute could benefit from PFR to mitigate coastal flooding. Local authorities such as Aberdeen City, Aberdeenshire, Dumfries and Galloway, Perth and Kinross and the Scottish Borders could benefit most from PFR to protect against fluvial flooding.
- Climate change analysis revealed that properties benefitting from PFR measures could increase by 30-70% in the future.

5.2 National level findings

5.2.1 Properties benefitting

To determine the proportion of properties that may benefit from PFR we checked the assessment of the total properties at risk against SEPA's estimate of flood risk. For a 200-year event this identified a total of 319,000 properties at risk of flooding from all sources. This value included all depths of flooding within properties and some double counting. Further breakdown of flood sources by local authority is provided in Section 5.3. This value has significantly increased since the previous JBA report (JBA, 2014), which quoted a value of 113,000. SEPA's National Flood Risk Assessment (NFRA) (2018a) has since been revised to include updated flood mapping and building footprints as opposed to using point datasets.

This difference between the calculated value and the quoted value of properties at risk of flooding, which sits at 284,000 (SEPA, 2018b), suggests that around 35,000 properties were double counted during the analysis (e.g. properties at risk from multiple flood sources).

However, we performed a check to identify our non-double counted value, which sat at 270,000. Therefore, approximately 50,000 properties were double counted.

A summary of the properties at risk is shown in Table 2. Surface water flooding poses the greatest risk to properties throughout Scotland, with almost double the amount of properties at risk at the 200-year event than fluvial flooding. It should be noted that it appears that the coastal data provided to JBA for analysis was based on limited available climate change scenarios for flood hazards and therefore the 30+CC flood depths are the same as those provided for the 30-year return period event without climate change. These results have been excluded from Table 4.

Table 2: Summary of properties at risk of fluvial, coastal and surface water flooding in Scotland, including duplicates (residential and non-residential combined)

Flood source	Return period							
	10yr	30yr	50yr	100yr	200yr	1000yr	30yr+CC	200yr+CC
	10% AP	3.33% AP	2% AP	1% AP	0.5% AP	0.1% AP	3.33% +CC AP	0.5% AP +CC
Fluvial	35,436	61,316	68,792	80,706	96,972	133,605	82,563	142,398
Coastal	7,598	13,706	15,583	17,902	20,090	27,971	-	37,883
Surface water	50,285	79,842	113,804	155,861	202,768	256,799	130,464	256,799
All	93,319	154,864	198,179	254,469	319,830	418,375	-	437,080

Residential and non-residential breakdownTable 3 (residential), Table 4 (non-residential) and

Table 5 (totals) show a summary of national level findings of properties most likely to benefit from PFR. It should be noted that the total counts are independent of each other. It is calculated that 64,000 properties could benefit from automatic resistance measures. However, if the resilience measures are installed in properties that flood most frequently, only 16,000 additional properties would benefit from resistance measures. Whether this is the case or not would depend on the funding and implementation mechanisms employed by responsible authorities.

Table 3: Summary of national level findings for the number of residential properties that may benefit from PFR measures at risk of fluvial, coastal and surface water flooding

Flood source	Resilience (10% AP)	Resistance (Auto, 3.33% AP)	Resistance (Manual, 2% AP)
Fluvial	16,563	28,442	32,282
Coastal	3,904	7,638	8,800
Surface water	22,557	33,982	49,754
All	43,024	70,062	90,836
Without duplicates	35,054	56,864	72,772

Table 4: Summary of national level findings for the number of non-residential properties that may benefit from PFR measures at risk of fluvial, coastal and surface water flooding

Flood source	Resilience (10% AP)	Resistance (Auto, 3.33% AP)	Resistance (Manual, 2% AP)
Fluvial	2,189	3,695	4,191
Coastal	1,059	1,504	1,727
Surface water	2,447	3,613	4,959
All	5,695	8,812	10,877
Without duplicates	4,844	6,688	8,130

Table 5: Summary of total national level findings for the number of properties that may benefit from PFR measures at risk of fluvial, coastal and surface water flooding (residential and non-residential)

Flood source	Resilience (10% AP)	Resistance (Auto, 3.33% AP)	Resistance (Manual, 2% AP)
Fluvial	18,752	32,137	36,473
Coastal	4,963	9,142	10,527
Surface water	25,004	37,595	54,713
All	48,719	78,874	101,713
Without duplicates	39,898	63,552	80,902*

**All properties would benefit from manual resitance measures. This total is therefore the total of properties identified as benefiting from PFR*

The results in table 5 above show that:

- Up to 81,000 properties could benefit from some form of manual resistance measures. Of this number, 64,000 could benefit from automatic measures.
- Of the total above, 40,000 properties may also benefit from resilience measures. Many of the 40,000 properties identified as potentially benefitting from resilience measures may also benefit from resistance measures.

The results of the assessment mean that potentially 30% of all properties at risk of flooding from any source may benefit from the uptake of some type of PFR measure (Table 2 and

- Table 5).

Comparing the calculated values to the previous baseline study conducted by JBA in 2014, the values previously calculated were 26,000 (10 year), 44,000 (30 year) and 51,000 (50 year). Previous research concluded that around 45% of properties would potentially benefit from PFR. However, the total number of properties at risk was only around one third of that reported in this updated assessment. There is approximately a 50% increase in the number of properties benefitting from PFR since the previous assessment, reflecting methodological changes and improvements in the underlying property dataset. It is also attributed to the improved understanding of surface water flood risk.

5.3 Regional findings

5.3.1 Properties benefitting

The regional analysis overlays the results against Scottish Local Authority boundaries. Results are presented in Figures 5-1 to 5-5. Tabulated results for this section are detailed in Annex D.

Figure 5-1 shows the percentages of properties at risk of flooding in each local authority (at the 200-year flood), the estimate of those that can benefit from PFR (assuming the higher resistance manual approach) and the corresponding percentage of properties that could be protected by PFR measures.

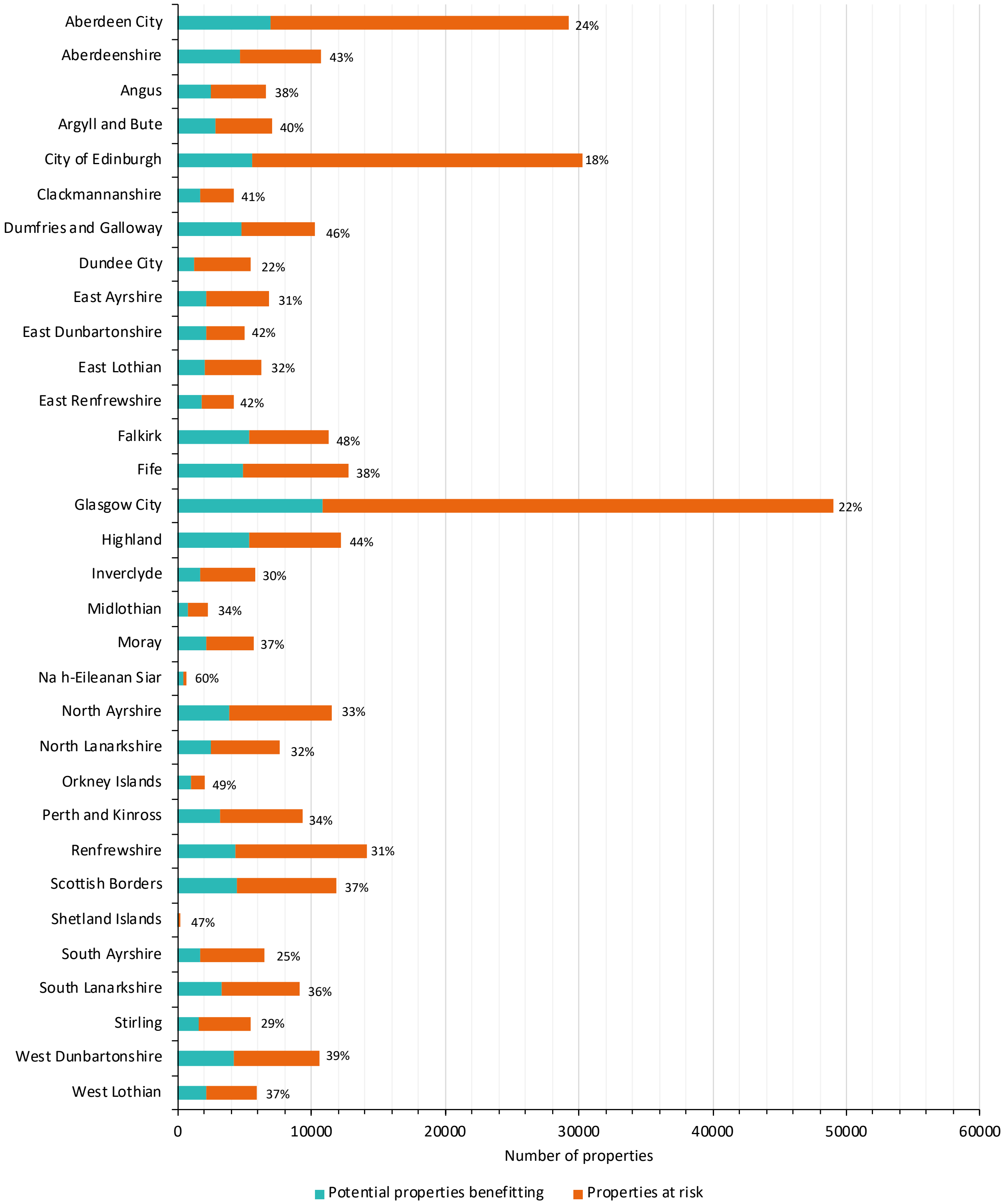

Figure 5-1: Percentages of properties at risk of flooding from all sources in each local authority that could benefit from PFR measures

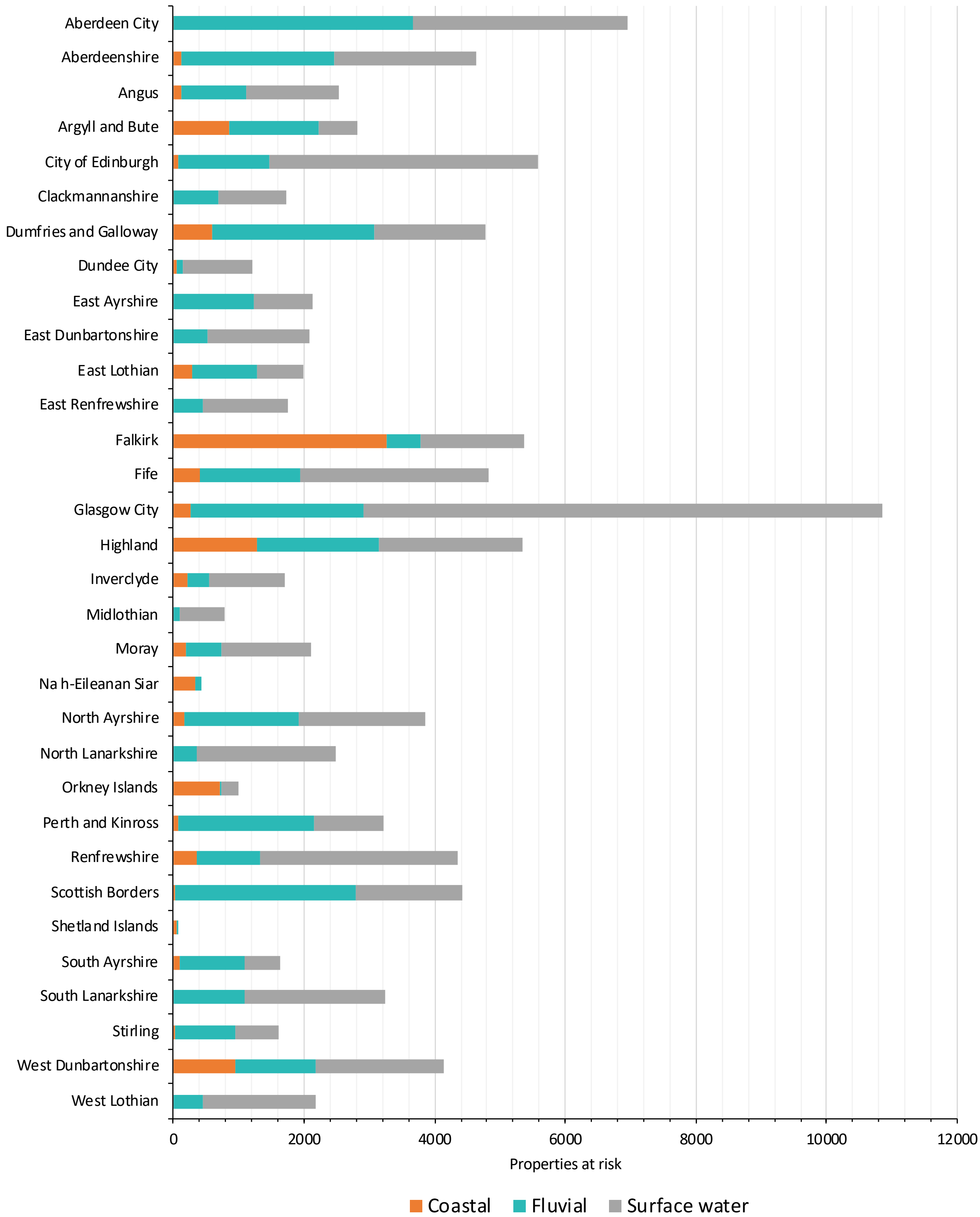

Figure 5-2 provides a total count of properties benefitting by flood source. It illustrates the high proportion of properties potentially benefitting from PFR for surface water flood risks, particularly in Glasgow, Edinburgh and Aberdeen.

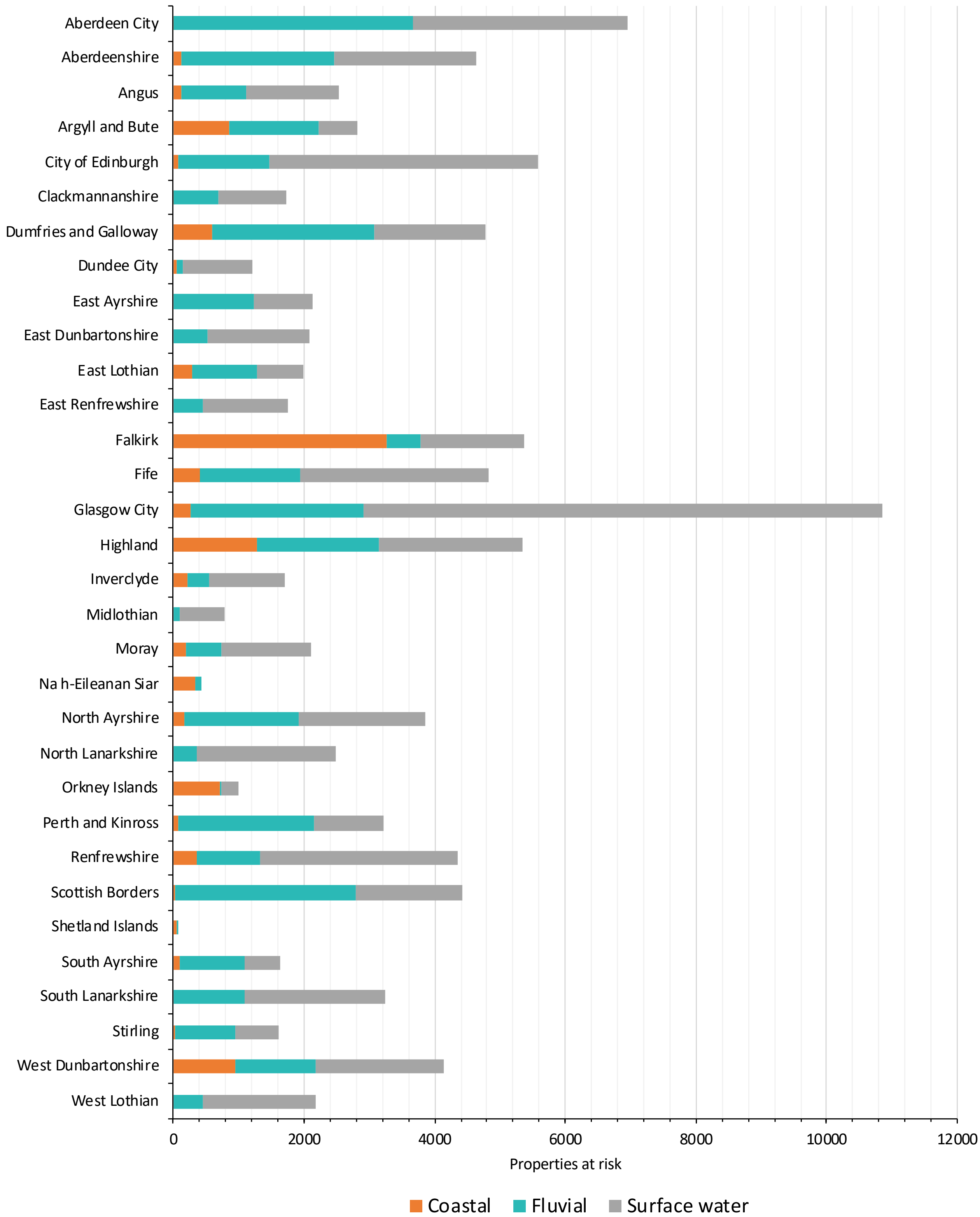

Figure 5-2: Breakdown of total properties potentially benefitting by PFR by local authority and flood source

Figure 5-3, 5-4 and 5-5 show the properties that could potentially be protected by PFR by fluvial, coastal and surface water flooding respectively. It should be noted that SEPA's NFRA 2018 data does not account for properties at risk from multiple flood sources. Further analysis would be required to correctly estimate total properties benefitting without double counting.

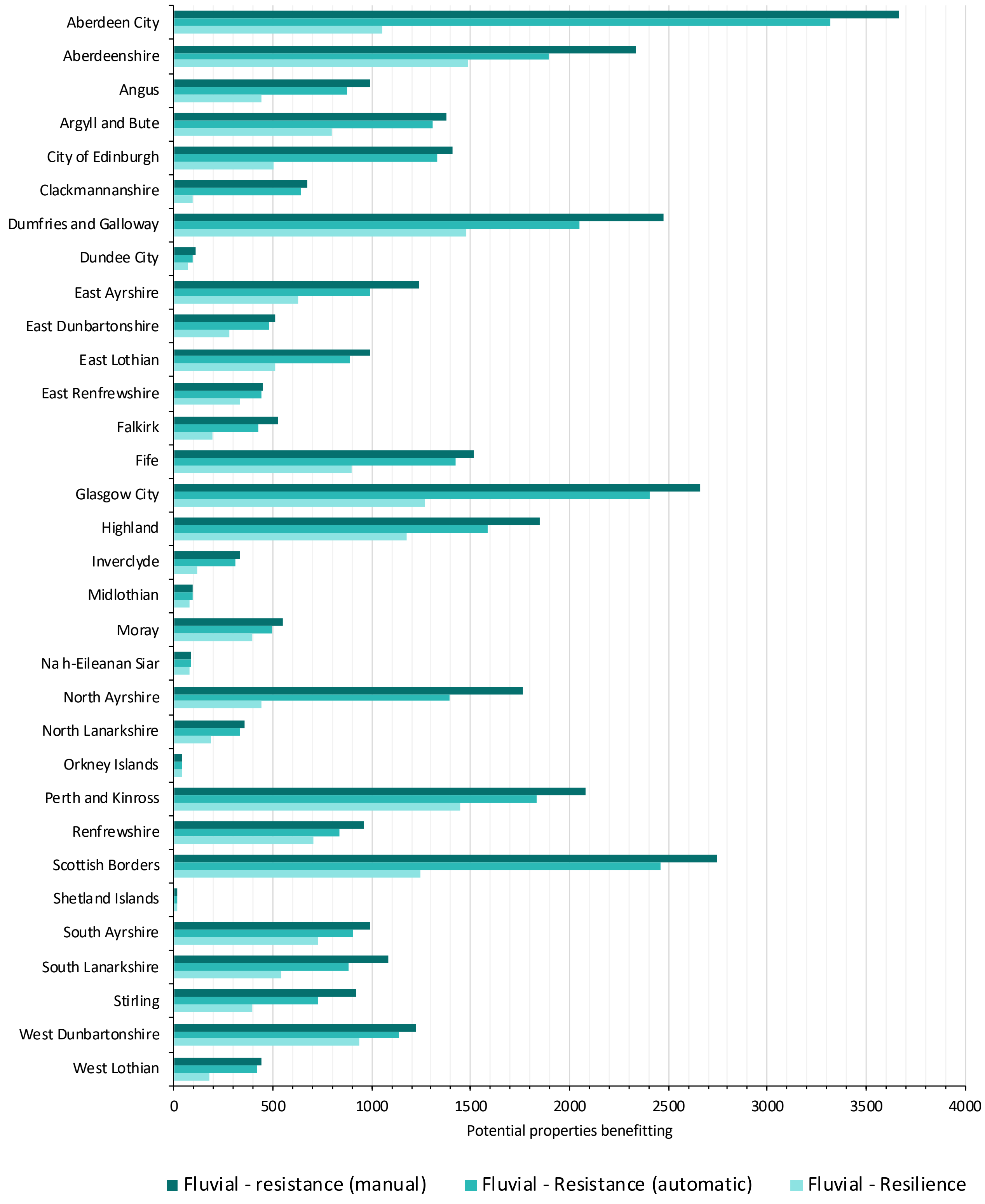

Figure 5-3: Breakdown of total properties that could benefit from PFR measures by local authority to mitigate fluvial flooding

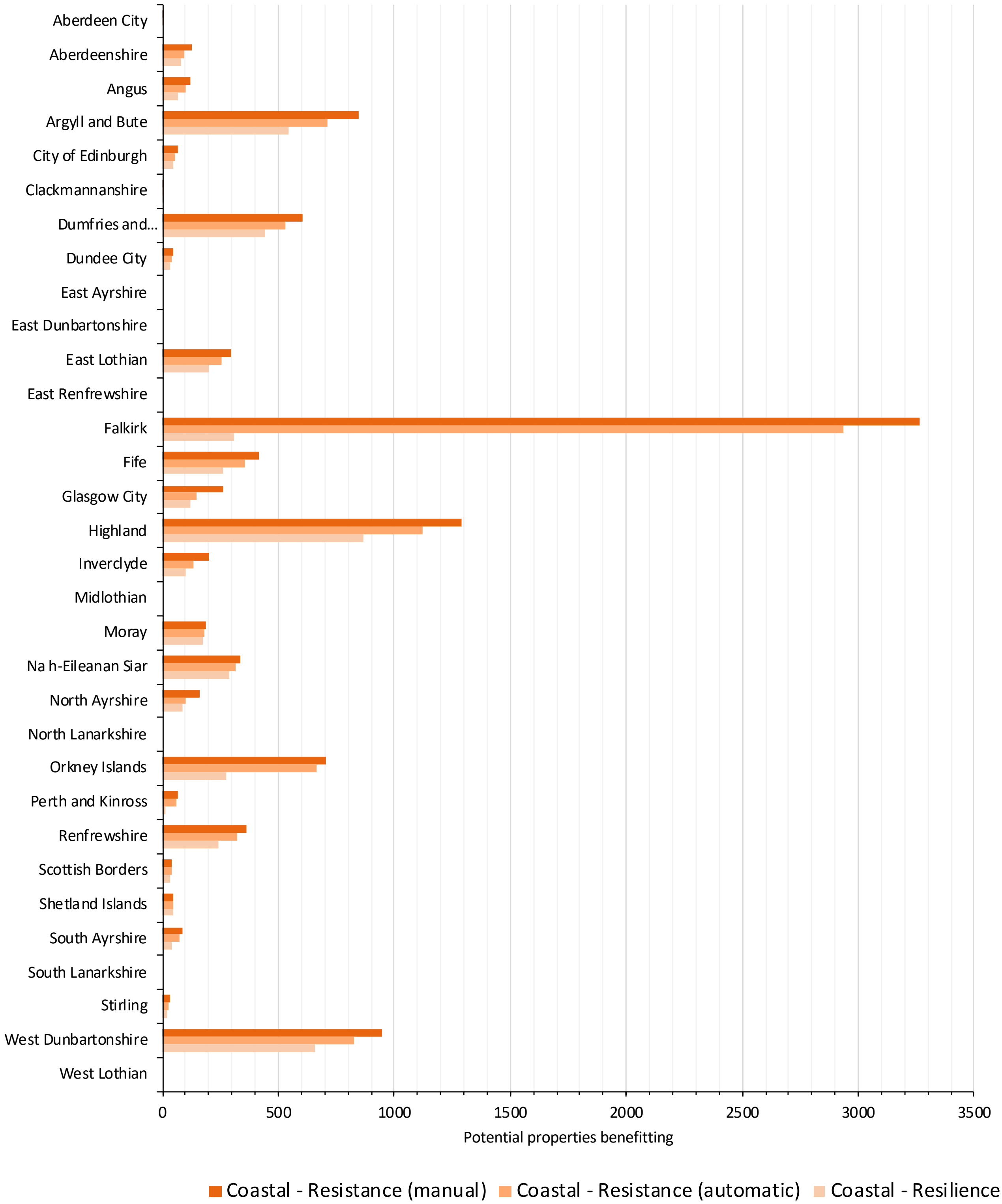

Figure 5-4: Breakdown of total properties that could benefit from PFR measures by local authority to mitigate coastal flooding

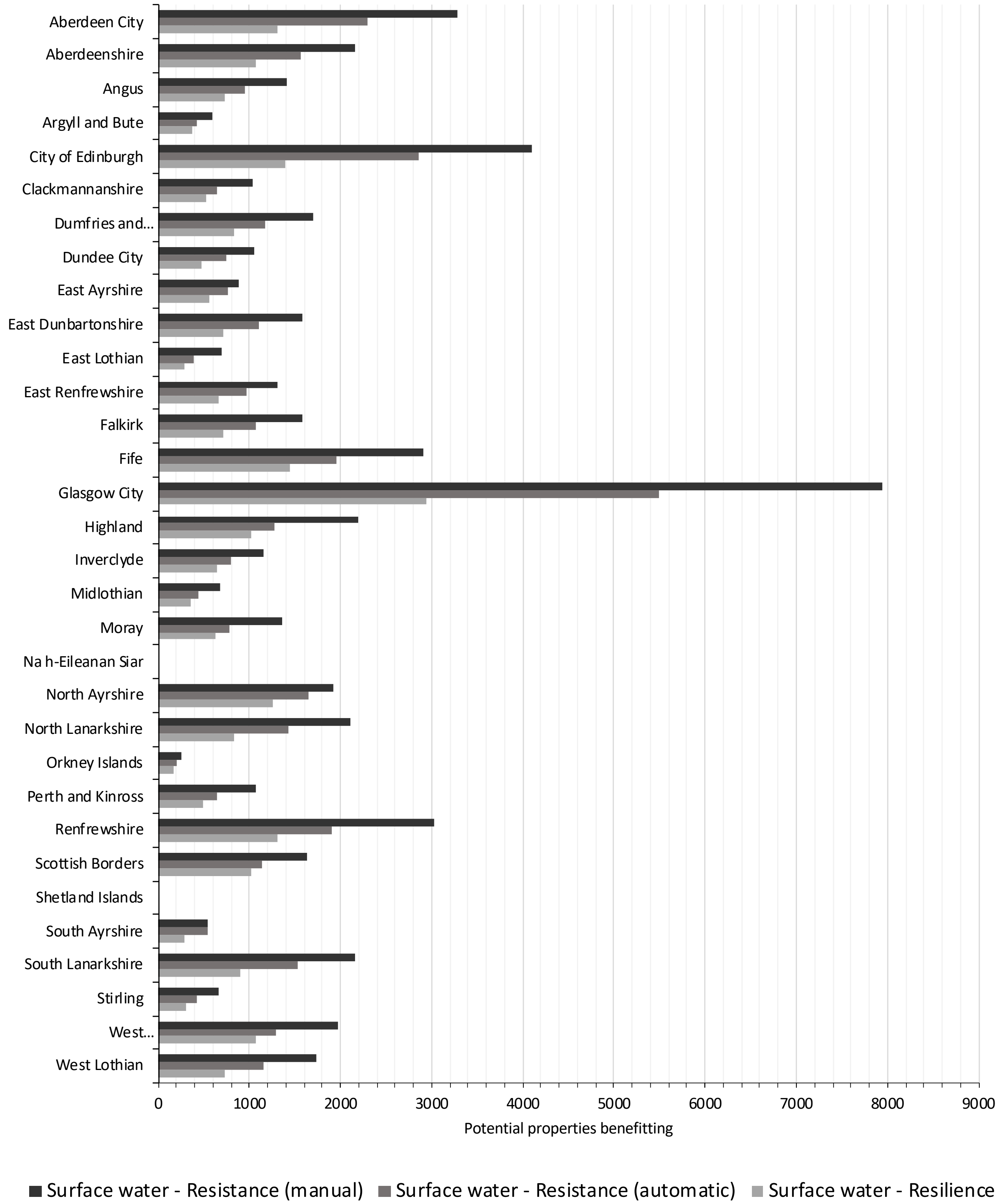

Figure 5-5: Breakdown of total properties that could benefit from PFR measures by local authority to mitigate surface water flooding

The results suggest overall, with most local authorities potentially benefitting from PFR on over 30-40% of properties, that there is considerable potential for the implementation of PFR measures across Scotland. It is interesting that some of the larger cities with the greatest risk have some of the lowest proportions of properties that could benefit. This is surprising as these have a high proportion of properties at risk from surface water flooding and one would expect these properties to benefit from PFR measures (lower flood depths). This could potentially show a link between greater surface water flood depths in cities compared to other more rural local authorities or could be related to property type, i.e. the larger proportion of tenements and flats within Scottish cities.

These results break down areas which are most likely to benefit from PFR measures, but do not suggest that this should be the preferred approach for any given area. Local authorities are advised not to solely rely on these figures due to the broad scale of data processing undertaken, but use them as supplementary data, backed up by specific local authority findings. These may include data gathered on specific areas prone to flooding, which may not be picked up by broad-scale data analysis.

Glasgow can be identified from Figure 2 as the local authority most at risk, mainly attributed to surface water flooding. It is therefore no surprise that Glasgow - and other cities such as Edinburgh and Aberdeen - benefits most from PFR measures to mitigate surface water. Glasgow has potentially 8,000 properties benefitting from PFR to mitigate against surface water flooding. Other local authorities such as Falkirk, Highland, and Argyll and Bute could benefit more from PFR to help mitigate the effects of coastal flooding, whereas Aberdeen, Scottish Borders and Glasgow benefit most from fluvial flood sources.

5.3.2 Comparison against the previous Scottish Government analysis

It is clear that the number of properties benefitting has increased significantly since the update to SEPA's NFRA. The number of properties in Glasgow benefitting from PFR (30 year) from a surface water flood source has also jumped significantly since the JBA (2014) report (700 to 5,200), suggesting that surface water flood mapping has significantly evolved, as coastal and fluvial benefits in this local authority seem to have both had a similar level of uplift (<50 to 200 for coastal, 500 to 2,400 for fluvial). This surface water trend is seen across almost all of the local authorities (generally around a six-fold increase).

Compared to the previous JBA (2014) report, there is a change in the local authority with the most benefitting properties. The previous report identified Aberdeen, Dumfries and Galloway, and the Scottish Borders as benefitting most from PFR (fluvial) with Aberdeen benefitting around 2,800 properties. The findings from this report show that PFR (fluvial) in Aberdeen could potentially benefit 6,000 properties, further illustrating the improved levels of mapping between the two datasets. However, this value may be accentuated as a result of double counting.

5.4 Climate change analysis

PFR helps to mitigate the short to medium term impacts of climate change on flood risk. Climate change analysis revealed that present day to future (2080) increases in existing properties that could benefit from PFR are in the order of 30-70% (see Table 10).

Resilience measures are beneficial for the most frequent of flooding events (e.g. 10, 30, 50 year – see Glossary); there is potential for around 145,000 properties to benefit from PFR in the future (although this includes around 35,000 double counted properties). Table 6 shows the breakdown of the number of properties benefitting by flood source in the present day and for future climate change projections, and Figure 5-6 illustrates this graphically.

Table 6: A summary of the estimated increases in the number of properties potentially benefitting from PFR by flood source, in the present day and 2080

	Resilience (10% AP)	Resistance (Auto, 3.33% AP)	Resistance (Manual, 2% AP)
Return period	10	30	50
Fluvial 2018	18,752	32,137	36,473
Fluvial 2080	24,512	44,130	53,250
Fluvial increase	5,760 (31%)	11,993 (37%)	16,777 (46%)
Coastal 2018	4,963	9,142	10,527
Coastal 2080	7,492	13,201	15,856
Coastal increase	2,529 (51%)	4,059 (44%)	5,329 (51%)
Surface water 2018	25,004	37,595	54,713
Surface water 2080	42,156	63,045	76,027
Surface water increase	17,152 (69%)	25,450 (68%)	21,314 (39%)
All 2018	48,719	78,874	101,713
All 2080	74,161	116,403	145,132
Total increase	25,442 (52%)	37,529 (48%)	43,419 (43%)

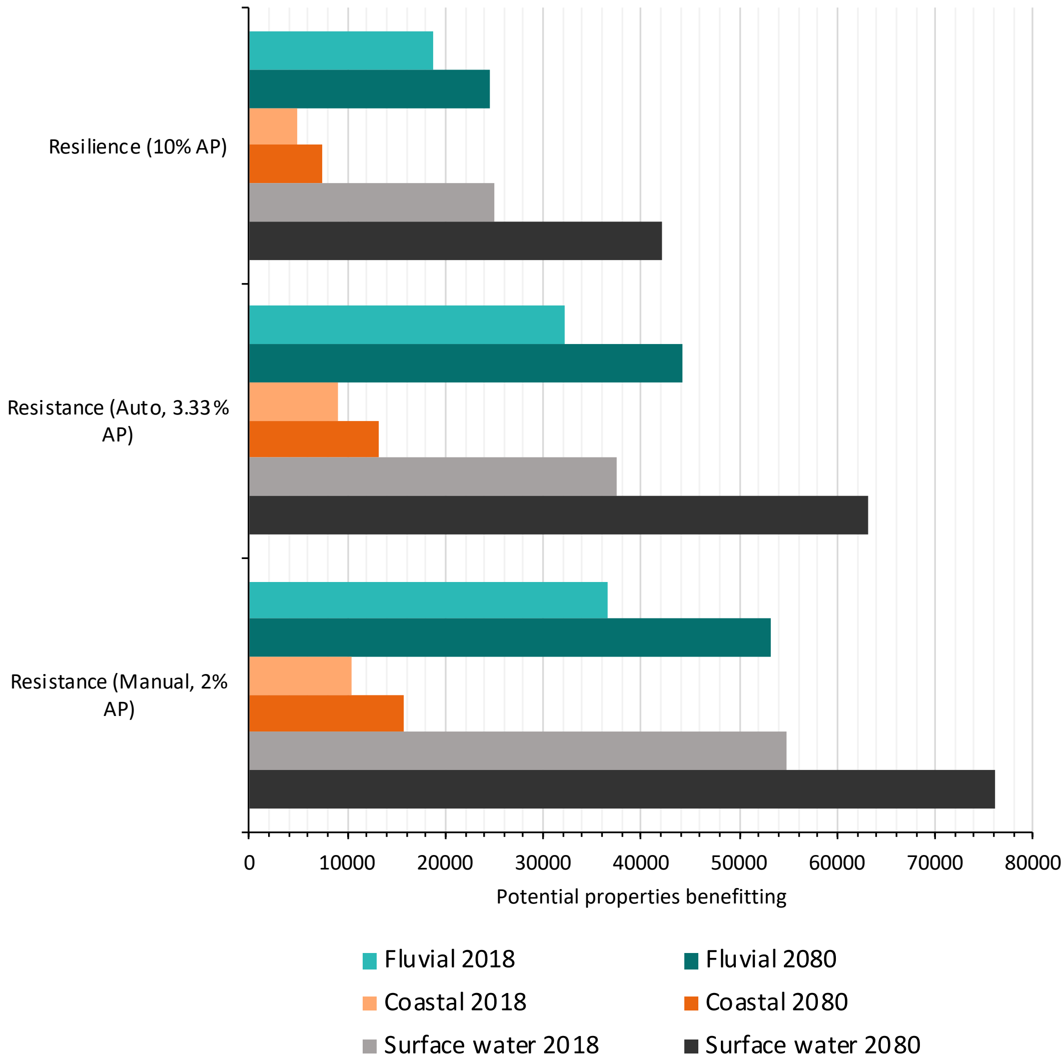

Figure 5-6: The number of properties potentially benefitting from PFR measures by flood source in the present day and 2080

The increase in the number of properties benefitting for different flood sources range from 5,800 to 16,800 (31-46%) for fluvial sources, 2,500 to 5,300 (44-51%) for coastal and 17,100 to 25,500 (39-69%) for surface water. Surface water flooding has the most variation of the three, perhaps due to the increasing flood depths with increasing return period; it seems that around the 50-year return period more property flood depths start to exceed 0.6m, and thus the percentage increase in properties benefitting with climate change decreases. However, this does not apply to coastal and fluvial flood sources as there are a greater number of property flood depths less than 0.6m allowing more properties to benefit from PFR.

5.5 Summary

The above analysis suggests that up to 81,000 properties could benefit from some form of manual resistance measures. Of this 81,0000, approximately 64,000 properties may benefit from automatic resistance measures, while approximately 40,000 properties may benefit from resilience measures. Many of the 40,000 properties identified as potentially benefitting from resilience measures may also benefit from resistance measures. All these estimates exclude double counted properties. The figures should be considered to be upper estimates as schemes are currently being proposed across Scotland that will reduce the number of properties at risk.

A summary of properties that may benefit from PFR is shown below in Figure 5-7. The chart includes both residential and non-residential data; the number of non-residential properties as a proportion of each flood source is shown.

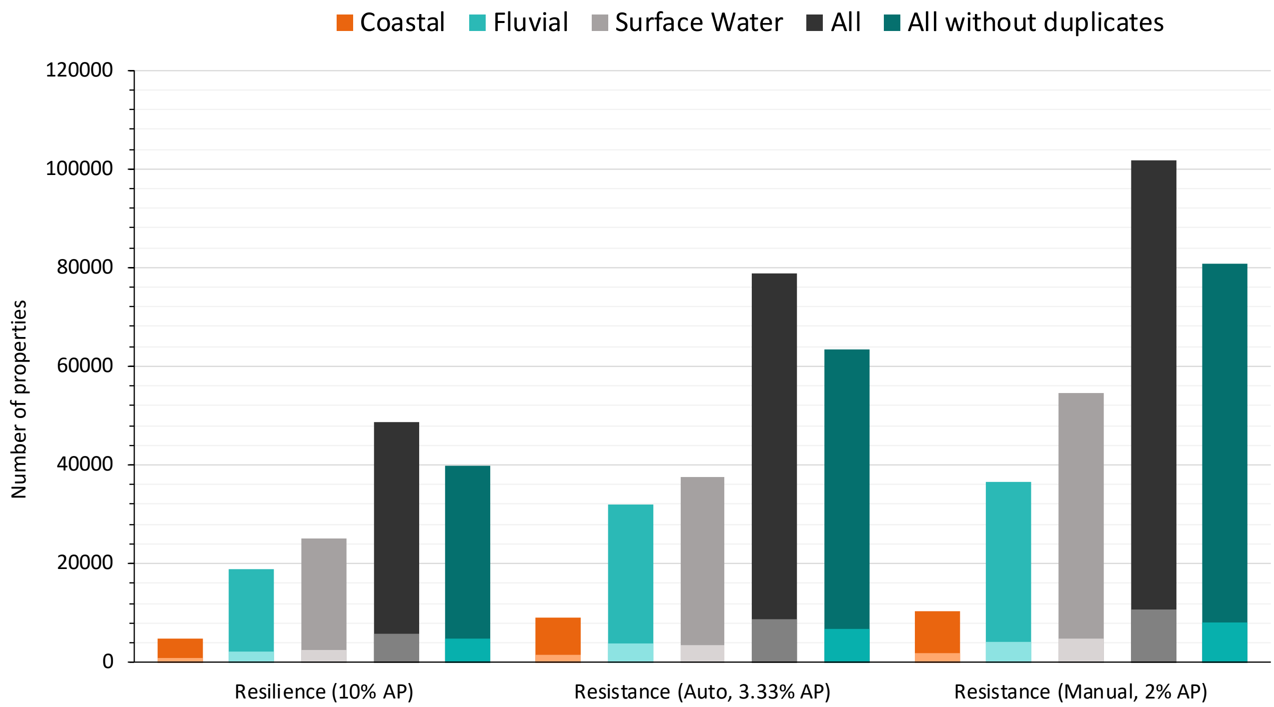

Figure 5-7: Summary of properties that could benefit from PFR, and the proportion of each flood source which is non-residential

The following conclusions can be drawn from the analysis:

- PFR measures appear to provide the greatest benefit to properties at risk from surface water flooding. This is partly due to the fact that surface water flooding generally occurs with shallower depths than coastal and fluvial flooding, but is also because Scottish properties are more likely to be at risk from surface water flooding (approximately 70% of all properties at risk are at risk from surface water flooding).

- Due to developments in datasets and methodologies, more than double the number of properties could benefit from PFR compared with previous Scottish Government analysis.
- Potentially a third of all properties at risk of flooding from any source could benefit from the uptake of some type of PFR measure.
- Some of the larger cities with the greatest risk, such as Glasgow, Edinburgh and Dundee, have the highest number of properties that could benefit from PFR measures to mitigate surface water flooding. Local authorities such as Falkirk, Highland and Argyll and Bute could benefit from PFR to mitigate coastal flooding. Local authorities such as Aberdeen City, Aberdeenshire, Dumfries and Galloway, Perth and Kinross and the Scottish Borders could benefit most from PFR to protect against fluvial flooding.
- Climate change analysis revealed that present day to future (2080) increases in properties that could benefit from PFR are in the order of 30-70%.

6 Properties benefitting from PFR: Qualitative analysis

6.1 Introduction

To assess the uptake of PFR across Scotland, we designed and distributed a questionnaire to local authorities, flood groups and other stakeholders to gather information on what, how and when measures were installed, and to obtain as accurate a number as possible for the number of properties that currently have PFR installed.

This enabled us to gather and collate responses from residents and local authorities on the uptake of PFR within a variety of local authority areas. It should be noted that some respondents did not provide contact details for follow-up on certain answers and we have therefore interpreted these responses accordingly.

6.2 Methodology

The questionnaire was distributed using the same platform. It was designed to gather information on the following:

- Information on the property (owned, rented etc.)
- PFR type (resistance, resilience)
- When it was installed
- Who installed the measure(s)
- How effective it has been

All of these factors allowed a picture to be built up of PFR uptake across Scotland and an approximate estimate of the number of properties benefitting. The questionnaire was distributed to local authorities using SCOTS (Society of Chief Officers of Transportation Scotland) and also distributed to local flood groups through the Scottish Flood Forum (SFF), with the focus on collating information on the national uptake of PFR.

A number for the amount of properties currently benefitting from PFR across Scotland was estimated using the questionnaire responses that stated that their property had PFR, by taking the number of properties the questionnaire was being filled out for.

The questionnaire can be found in Annex C.

6.2.1 Limitations

Due to some inconsistencies in the results of the questionnaire (i.e. the respondent saying they have no PFR measures but then stating the measures that are installed), some more detailed analysis of the responses was necessary. We have assumed that some of these discrepancies may be attributed to the technical nature of some terminology in the questionnaire and misunderstanding by some respondents. We suggest that respondents are provided with information on understanding PFR measures and terminology in future, before contributing to research, as some respondents appeared to have not fully understood the questionnaire.

Some responses with reference to the number of properties protected by PFR are vague, for example ‘multiple properties’, ‘30+’, ‘village’. We have therefore had to make reasonable estimates for these answers for example, a village was assumed to be approximately 20 properties. One response had to be removed as the respondent had misunderstood the questionnaire and therefore could not be used for analysis.

7 Results of qualitative analysis

7.1 Key results

We have estimated that approximately 1,400-1,500 properties are currently protected by PFR, up by an estimated 300 since 2014. This number was estimated using responses from the questionnaire. We have estimated the number of properties with PFR delivered by local authorities (through subsidy schemes) to be approximately 280. Around 20 properties had PFR delivered by local flood groups and less than 10 by individuals.

Results indicate that the most popular type of PFR is resistance measures. Only 8% of respondents said they had resilience measures. This is likely to be due to PFR measures being provided across Scotland by subsidy schemes and the higher costs associated with resilience measures. Door guards and airbrick covers are the most popular types of resistance measure.

The majority of PFR measures have been used on residential properties in Scotland, with very few non-residential properties identified as having used PFR approaches, although it may be because commercial property owners are not in flood groups or do not notify their local authority of improvements.

7.2 Results of questionnaire

7.2.1 PFR measures

This section deals with information specific to the installation of PFR measures including type, effectiveness and how measures were installed. Figure 7-1 shows the percentage of respondents who have PFR measures installed in their property(s).

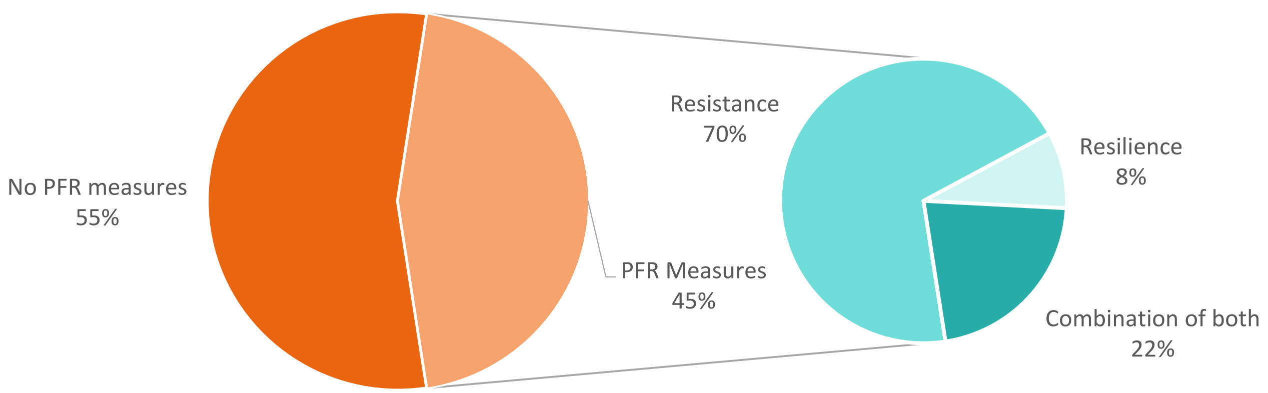

Figure 7-1: Percentage of respondents who have PFR measures installed, and whether these are resistance, resilience or both

27 of the 51 respondents stated that they did not have any PFR measures, therefore details on the specifics of PFR measures are only based on 45% of the total number of respondents. Of the respondents who have PFR measures installed, 70% were resistance, 8% resilience and 22% a combination of both.

Resistance measures appear to be the more common solution. This may be because, in general, they are cheaper than resilience measures, which involve changing the configuration of a building (i.e. replacing kitchen units, separating electrical circuits, replacing wall materials).

7.2.2 Installation of PFR

CIRIA's Code of Practice (CoP)[4] notes that the proper construction and installation of PFR measures ultimately helps deliver the necessary levels of resistance and resilience required to meet the needs of both the building and the end users. We are therefore interested in who installed the respondent's PFR measures, shown in Figure 7-2.

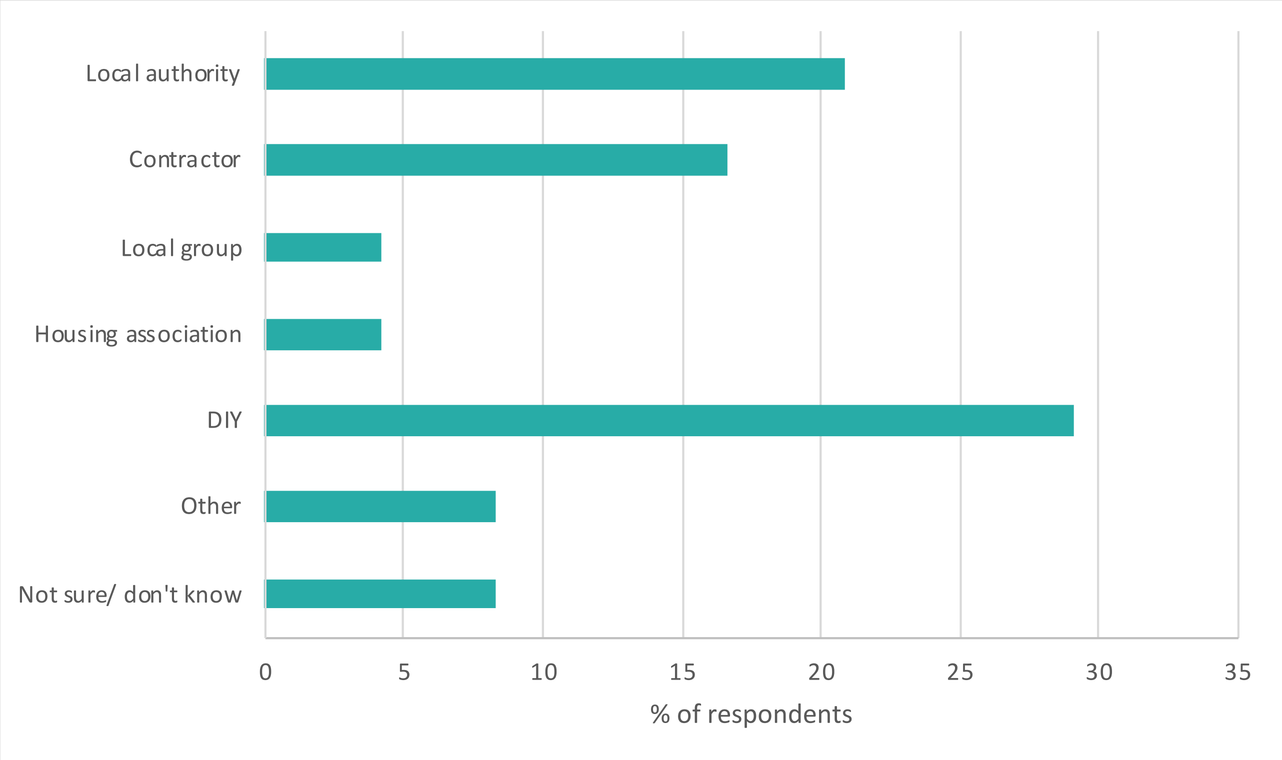

Figure 7-2: Who installed the respondent's PFR measures

DIY installation is the most common method with over 25% of respondents having installed PFR measures themselves. Local authorities are the next most dominant, installing measures for over 20% of respondents. It is unclear whether some of these responses refer to local authority subsidised products physically installed by the homeowner, or products directly installed by the local authority. Additional categories include contractors (over 15% of responses), local groups, housing associations and 'other'.

The 'other' category comprises community councils and Scottish Water. One example involved Scottish Water installing PFR resistance measures on a respondent's property in 2007, including air bricks and flood doors. Subsequent flooding in January 2008, inundated many properties on the street. The PFR measures proved ineffective as the depth of flooding was too great. If a property is expected to flood above 0.6m, then the likelihood of resistance measures working is minimal. This property would have therefore benefitted more from resilience measures. Clackmannanshire Council and Scottish Water have since undertaken a joint solution to flooding caused by the drainage network in June 2008, as a result of the January flooding.

One respondent who answered 'community' said that their village installed PFR measures supplied by the council, although this could mean that certain villagers install measures for the community, or the community installs its own measures (DIY). Another respondent explained that the Community Council for Bankfoot, Perthshire, had installed their measures via its Flood

4 CIRIA, 2019. RP1055 - Code of practice for property flood resilience. London: CIRIA.

Resilience Arm. A number of respondents did not know who installed their measures. This could simply be because they purchased the property with the measures already installed.

Overall, the fact that 25% of respondents report they have installed PFR measures themselves suggests that best practice is not always being followed in Scotland. This therefore does not align with the Scottish Government's 'Blueprint' guidance[5], nor the CoP. Further work is needed to ensure that suitable subcontractors are used.

7.2.3 Resistance measures

Residents who had resistance measures installed were asked what the measures were. Figure 7-3 shows the responses to the types of resistance measure respondents have in their property.

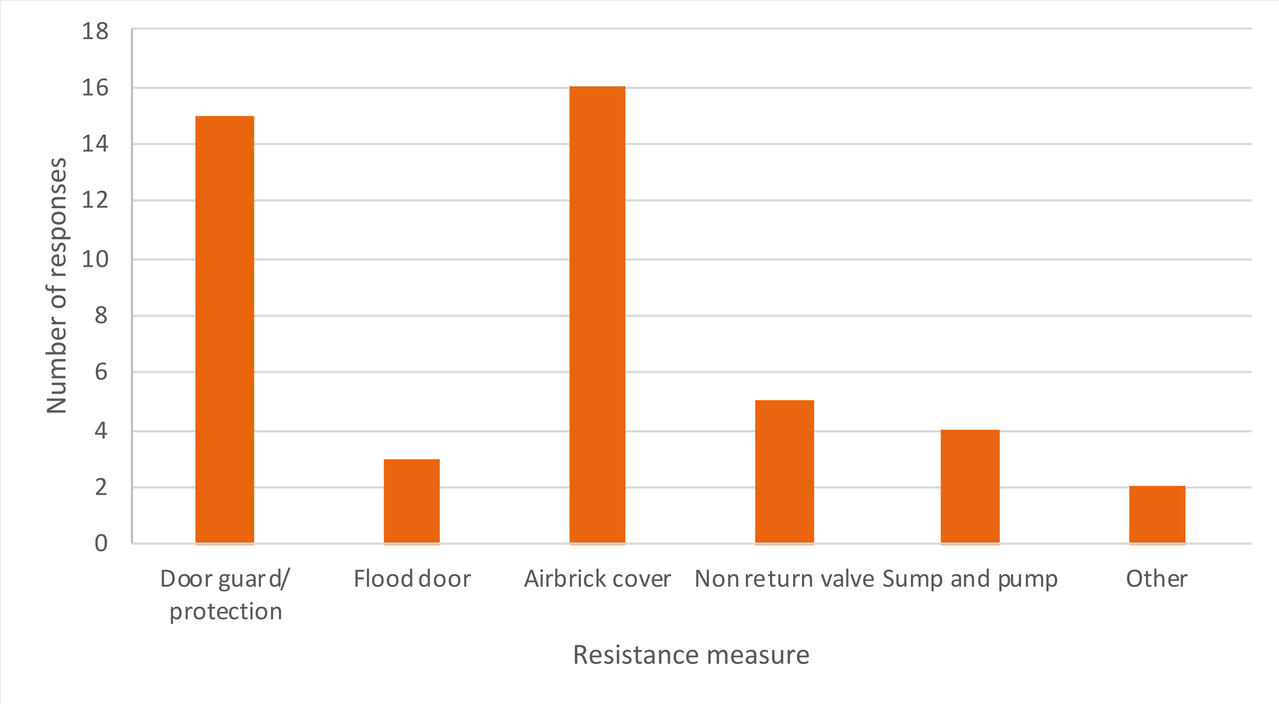

Figure 7-3: Types of resistance measure installed

Airbrick covers are the most common followed by door guard/protection. It may be that these are the most common as a result of government subsidies or PFR schemes from the Scottish Borders/Dumfries and Galloway. We know that one flood door was installed by Clackmannanshire Council, the other two were DIY; most other DIY installations are airbrick covers, as these are cheap and easy to install.

Five responses mentioned non-return valves. However, the general trend is that these are installed by contractors, Scottish Water or housing associations, as they are more challenging for the average homeowner to install. The 'other' category comprised smart air bricks and window guards (for French windows and a garage door).

5 JBA Consulting, Pettit, A. 2014. Assessing the Flood Risk Management Benefits of Property Level Protection - Final report. Edinburgh: Scottish Government.

7.2.4 Resilience measures

Resilience measures were broken down into floors, walls and interiors. Details of these measures are provided in the Glossary. Figure 7-4 shows the proportion of responses for each of these three categories, and 'other'.

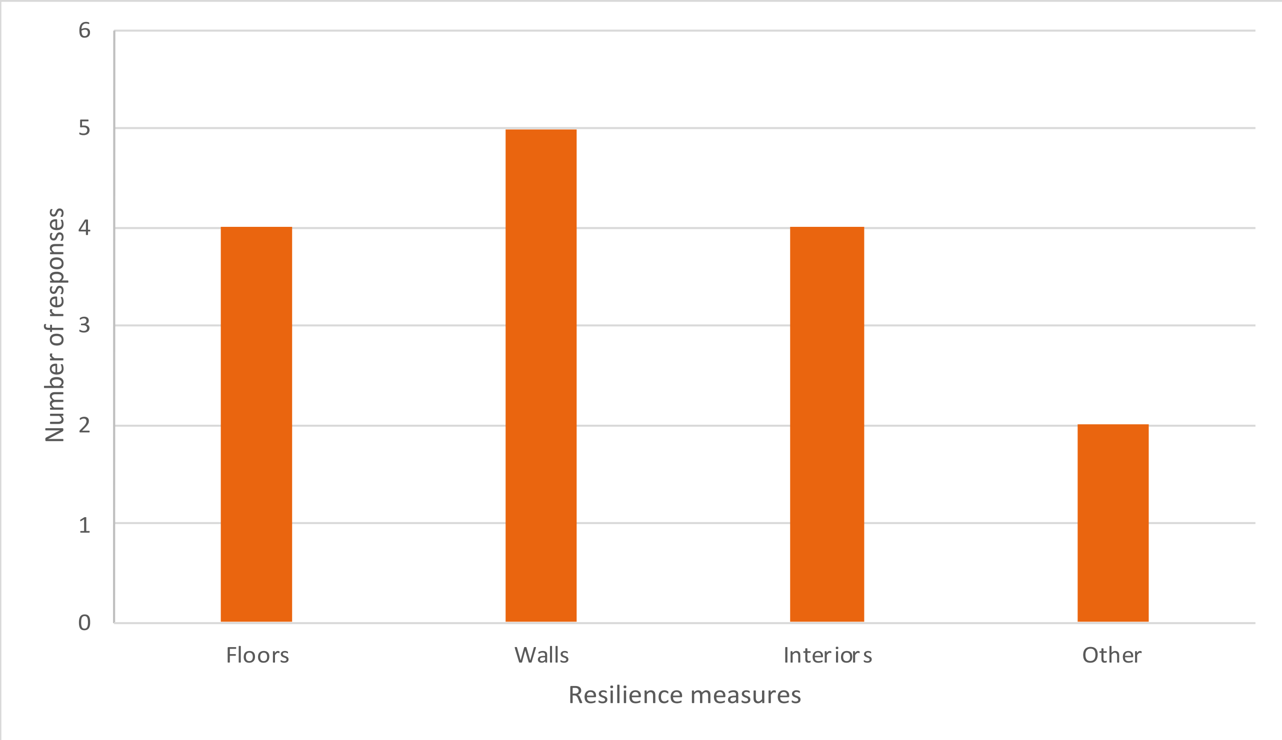

Figure 7-4: Types of resilience measure

Floor and interior resilience measures have four responses each, wall measures five responses, and 'other' resilience measures two. 'Other' measures include moving precious belongings upstairs when a flood is expected and improving garden drainage. In addition to this question, respondents were then asked to specify which measures they had taken within each category.

Floor resilience measures are designed to reduce the impact of flood waters on property floors. Responses included those from Dumfries and Galloway's subsidy scheme, Bankfoot Community Council and Aberdeenshire Council. However, as these responses accounted for approximately 550 properties in total, it is impossible to determine the scale of resilience measures implemented across the whole of Scotland.

Resilience measures relating to wall modifications incorporate a range of methods to make walls more resilient to flood water. Replacing wall insulation and gypsum plaster were the most common responses. Dumfries and Galloway Council mentioned that these measures were used in the past and undertaken as part of flood repair works.

Interior resilience measures refer to how interiors can be modified to make a property more resilient to flooding. Similarly, with wall and floor resilience measures, interior measures only have four responses, two of which have selected all measures.

7.2.5 Effectiveness of measures

In addition to types of PFR, we also gathered information about the effectiveness of these measures (Figure 7-5).

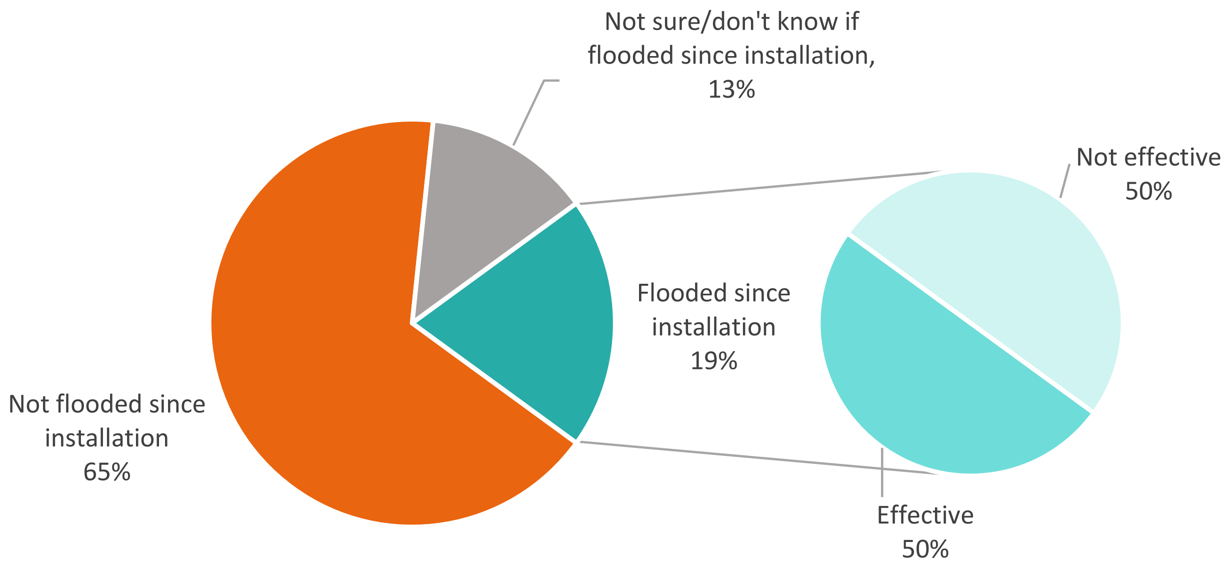

Figure 7-5: Effectiveness of PFR measures

Only 19% of the respondents who had PFR had had floods since installation; 50% said the measures were effective, and 50% said they were not effective. One respondent in Clackmannanshire said the flood gates installed were ineffective:

> *"'Originally installed by Scottish Water in 2007 following external sewer flooding. River Devon flooding in 2008 topped flood gates on doors and flood water inundated the property. PLP on air bricks and doors were ineffective against flood levels."*

Homeowner, Clackmannanshire

Many respondents had not been flooded since installation, and therefore could not comment on the effectiveness of the measures. Not all respondents who said the measures were ineffective gave reasons.

7.2.6 Post-installation surveys and maintenance

We also investigated how many of the respondents had surveys after installation (Figure 7-6) and maintenance agreements (Figure 7-7) Surveys were carried out by a range of persons, including Scottish Flood Forum and chartered surveyors; 63% of respondents had not had a post-installation survey.

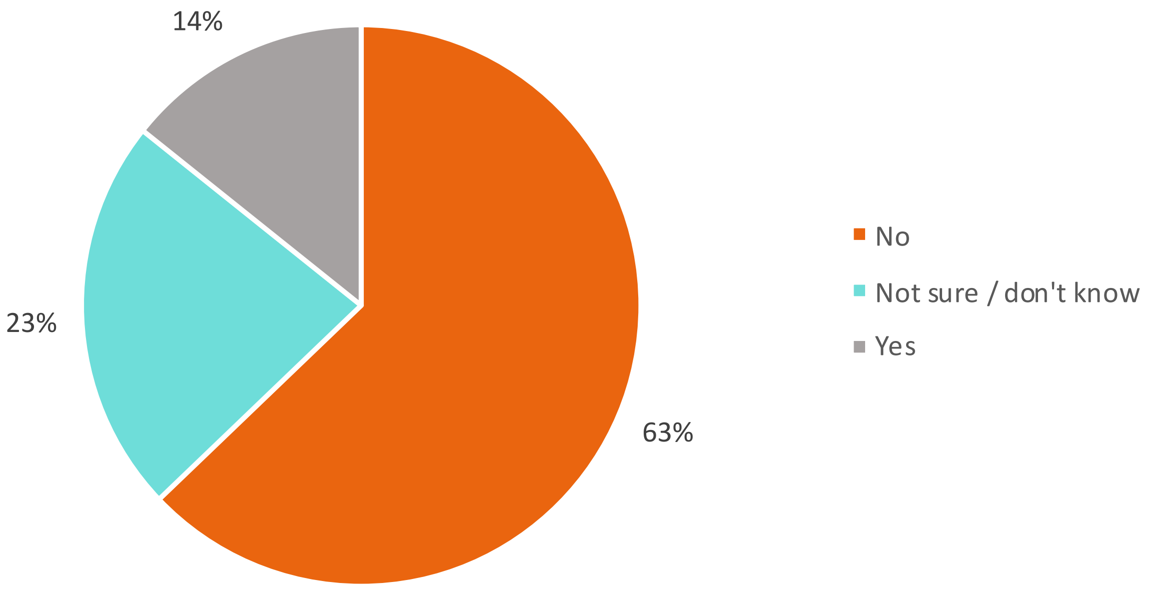

Figure 7-6: Percentage of respondents who had post-installation surveys

The above suggests that there is still some way to go in Scotland in terms of following best practice guidance and the CIRIA's CoP in terms of handover procedures. It is generally accepted that commissioning and handover procedures are critical to delivering the levels of PFR success rates required by end users. Failure to undertake these risks end users not understanding how to prepare for a flood and the installation needed.

Only 8% of respondents said they had maintenance agreements (Figure 7-7). Most of those with PFR measures maintain the measures themselves, whereas local councils are responsible for others. Clackmannanshire Council and Aberdeenshire Council were local authorities mentioned as being responsible for maintenance. One respondent explained the importance of understanding warranties associated with PFR measures:

> "*We had in our contract with the fitters that they would take this warranty on if this happened, so they now cover the guarantee for 10 years. For flood doors, the main parts that break are spindles, door locks etc. and these are usually NOT covered within flood doors 10 year guarantees - very key to look at the wording of the guarantees and get this ironed out pre-work or local authorities will be left with huge bills on their hands and taking forward PLP/PFR schemes will be un-economical and won't happen.*"

Local Authority Member, Scottish Borders Council

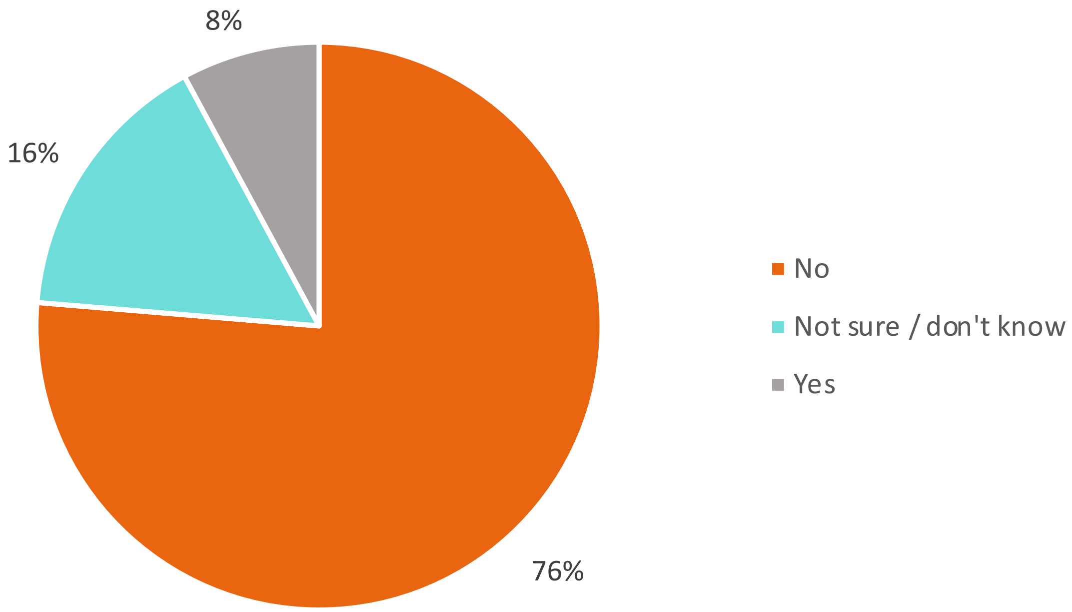

Figure 7-7: Percentage of respondents who have warranties/ maintenance agreements

7.3 PFR uptake in Scotland

7.3.1 Property and respondent information

Analysis has been carried out on the results based on the methodology outlined in Sectionn 6. Figure 7-8 shows a pie chart of the relationship of each of the respondents to the property/properties.

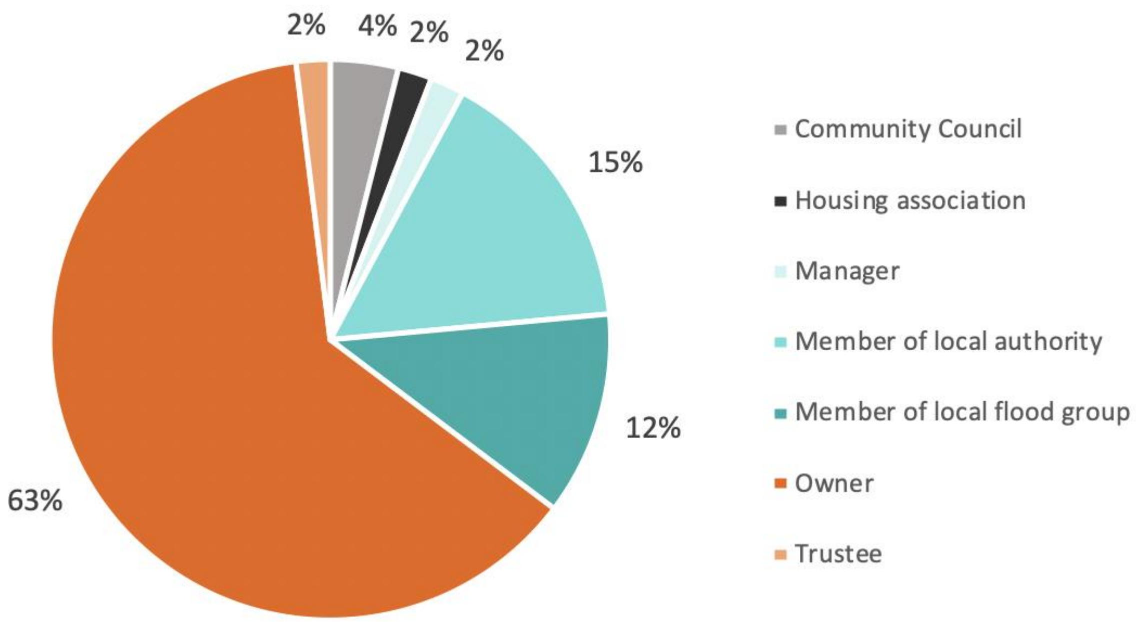

Figure 7-8: Pie chart showing relationship of respondent to property/ properties

The majority (63%) of respondents were homeowners, followed by members of local authorities (15%). Other respondents included community councils, housing associations, property managers and members of local flood groups. Notable responses to this question included Scottish Borders Council, Dumfries and Galloway Council and Kembhill Park Flood Group, which have implemented PFR within their communities.

We followed up Scottish Borders' response to get a breakdown of the property counts, as it had reported large numbers of properties with PFR. Scottish Borders Council has implemented a number of schemes within the area which have been initiated as subsidy schemes, where residents are given products for 'free' (schemes funded by the Council). The Council stated that 64 properties have benefitted from these schemes. These schemes include the following:

1. Peebles PLP (Property Level Protection) Scheme (2017/18). This included 39 properties which were supplied with flood doors, barriers, airbrick covers, pumps and non-return valves.
2. Eyemouth PLP Scheme (2018). Included supply of 17 properties with flood doors.
3. Jedburgh (Skiprunning Burn) Flood Protection Scheme (2015/16); 8 properties were supplied with timber flood doors as part of this scheme.

In addition to these schemes, Scottish Borders Council runs a subsidised flood product scheme. This is an initiative, ongoing for the last 12 years, in which the Council buys in flood products such as flood gates or airbrick covers and sells them on to residents at a subsidised price. The Council estimates around 241 properties have benefitted.

Scottish Government provided grants of £1,500 to owners who's properties were flooded during Storms Desmond or Frank in 2015/16. In the Scottish Borders Council area, there was an additional discretionary grant available from the Council. The Council has 73 properties on record as having been given grants. It is not known, however, if the Council checks whether the PFR has been installed and used correctly.

In total, the Council has reported 378 properties that have some level of PFR in the Scottish Borders, with the caveat that not all properties will be protected to the same standard. For example, some properties may be protected for frequent flooding (e.g. 5/10-year return period) but not for the less regularly occurring 200-year flood.

Dumfries and Galloway Council also has a subsidy scheme in place for PFR products including flood gates, smart airbricks and airbrick covers. Similar to the Scottish Borders, this subsidy scheme offers heavily discounted products for residents at risk of flooding and has been running since 2010.

Three of the respondents were from one flood group suggested that none of the houses had PFR, despite a history of flooding in the area. Houses within the area are wooden kit houses built on a concrete raft, which members of the flood group have said do not lend themselves to individual flood protection measures. However, a temporary flood barrier was built after Storm Frank until a permanent barrier can be constructed. Respondent from another flood group explained how they work in partnership with the public and with charities to help protect properties in the area, and is regularly called out to deal with flood events.

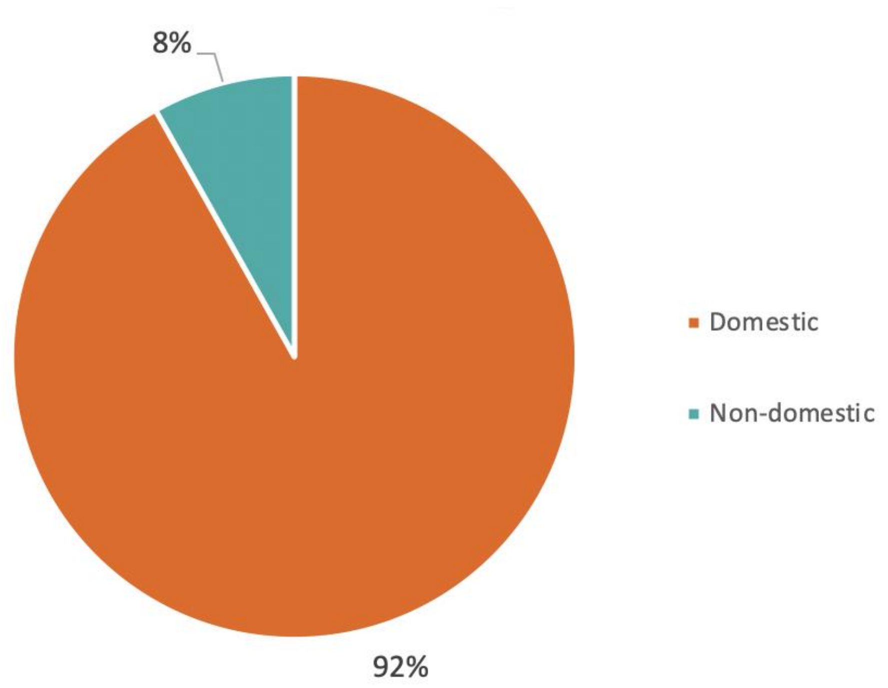

Figure 7-9 shows the percentage of respondents who filled out the questionnaire for residential and non-residential properties.

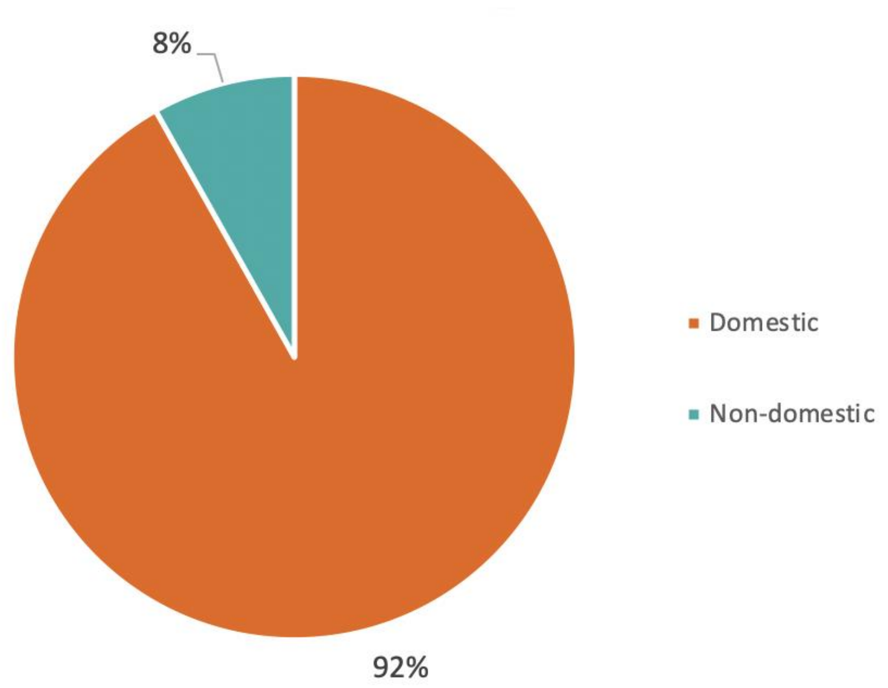

Figure 7-9: Respondents who answered for residential (domestic) versus non-residential (non-domestic) properties

92% of the responses were for residential (domestic) properties, but several of these responses were for multiple properties (varying from 5 to an entire local authority in one case). Only 16 properties were stated as non-domestic, with 13 of these from one respondent. One respondent answered the questionnaire for 500 properties which included both domestic and non-domestic properties (proportion unknown, but since 'domestic' was selected, we can presume they were mostly residential) within the region of Dumfries and Galloway. The responses were in relation to the subsidy scheme and encompassed both resistance and resilience measures.

7.3.2 Current estimates of properties with PFR

To estimate the number of properties that currently have PFR, we asked the respondents to state when the PFR measures were installed. This is so we could compare with the results from the previous JBA (2014) assessment and estimate the increase in uptake between 2014 to the present day. In 2014, the number of properties with PFR was estimated to be 600-1,000 (JBA, 2014). Many respondents did not know when PFR was installed, so we made an estimate based on those who provided a date from 2014 onwards. The total number of properties that have PFR was estimated irrespective of the date of installation.

From the results of the questionnaire, we found that 30 properties had PFR measures installed in 2014, 1 in 2015/16 and 22 in 2017. In the Scottish Borders, an estimated number for the number of PFR measures installed since 2014 was 255. In addition to these numbers, around 1,000 properties have had PFR installed through subsidy schemes in Dumfries and Galloway (2010), and Aberdeenshire (2011), but we do not know how many of these have been installed post-2014. We have therefore estimated the number of properties with PFR installed since 2014 to be around 300 and excluded the aforementioned subsidy schemes; this may lead to underestimation of this value. In reality, the number is probably boosted by some of the properties in the stated subsidy schemes which were excluded.

In total, we have estimated the number of properties in Scotland with some type of PFR installed between 1,400-1,500. This figure may include minor double counting from some homeowners, although this is not expected to impact the results significantly. We have also estimated the number of properties with some type of PFR delivered by local authorities (through subsidy schemes) to be approximately 280. Around 20 properties had PFR delivered by local flood groups and less than 10 by individuals. Therefore, it can be concluded that PFR installation has primarily been undertaken by local authorities over the last 5-6 years.

7.4 Summary

The qualitative questionnaire has provided an insight into the uptake of PFR across Scotland. However, 55% of respondents did not have PFR measures installed in their property. The results of the questionnaire have been presented based on the remaining 45% who did have PFR measures installed. The questionnaire conclusions are:

- Several local authorities have PFR subsidy schemes.
- Local authorities and SFF provide post-installation surveys to property owners.
- Since 25% of respondents stated that they had installed the PFR measures themselves, this suggests that further work is needed to ensure that Scottish Government guidance and the CIRIA CoP is followed.
- Failure to undertake post-installation surveys risks end users not understanding how to prepare for a flood or identify whether further PFR measure installation is needed.

We can draw the following conclusions about PFR uptake across Scotland:

- Between 1,400-1,500 properties are currently protected by PFR.
- The number of properties with PFR is estimated to have increased by approximately 300 since 2014, mainly as a result of schemes and assistance provided by local authorities. However, there may be other properties with PFR implemented by local authority subsidy schemes and individuals that have been excluded from this count.

- PFR has primarily been undertaken by local authorities over the last 5-6 years.

8 Further analysis that could be useful outwith the scope of this assessment

Several proposals for further analysis have been highlighted throughout this report as follows:

- Cluster analysis using the 'communities' dataset from the NFRA. This would allow local authorities to prioritise areas for the potential roll out of PFR.
- Overlaying areas of social deprivation. This could help identify communities at risk of flooding who may struggle to afford PFR measures and would therefore benefit from targeted schemes.
- Overlaying SEPA's Potentially Vulnerable Areas (PVAs) to identify additional areas where targeted action could be aimed and to help with understanding flood disadvantage.
- National datasets on buildings' listed status and SEPA's property database could be combined in the future to help identify properties' cultural status; this may influence whether PFR measures can be installed.
- If SEPA considers mapping indicative flood duration in future national mapping, this could help with future analysis of flood inundation timing.
- Application of a sensitivity test to manual resistance measures. This would allow areas which have flood warning systems to be prioritised for manual resistance measures, as opposed to areas with no flood warning.
- The questionnaire yielded some ambiguous results, attributed to respondents becoming confused about terminologies. To reduce these inconsistencies, respondents could be provided with background knowledge before filling out the questionnaire.
- It would be useful to establish and maintain a database of properties or locations currently benefitting from PFR.

9 Conclusions and discussion

9.1 Conclusions

The main aim of the study is to assess the uptake of PFR across Scotland. This includes how and when measures were installed, as well as identifying the flood risk circumstances whereby properties would benefit from PFR, both nationally and regionally. This study has provided analyses of data to inform these aims, considering both residential and non-residential properties at risk from fluvial, coastal and surface water flooding. Criteria set out in Section 3 were used to inform quantitative methodologies in Section 4, producing results of the baseline assessment in Section 5. We can draw a number of conclusions from the study.

9.2 Properties benefitting from PFR

Quantitative analysis included analysis in both GIS and Excel to identify the number of properties benefitting both at a national scale and a regional scale (local authorities), for both residential and non-residential properties. Conclusions from the quantitative assessment are as follows:

- Based on the criteria used in this research the total number of properties that could benefit from some type of PFR is 81,000. All these properties would benefit from manual resistance measures. Of the 81,000 we estimate that 64,000 properties would benefit from automatic resistance measures and 40,000 from resilience measures. For this reason these counts should not be added together. The choice of measure will be influenced by a range of factors including cost, flood source, availability of flood warning, property type and resident, available financial and practical support, and the logistics of the work.
- The greatest benefit of PFR measures is in areas where surface water flooding with depths less than 0.6m is prevalent.
- Due to developments in methodologies and datasets, the number of properties potentially benefitting from PFR has doubled compared to the previous Scottish Government (2014) analysis.
- Potentially around a third of all properties at risk of flooding, from any source, may benefit from the uptake of some kind of PFR measure.
- Some of the larger cities with the greatest risk, such as Glasgow, Edinburgh and Dundee, have the highest number of properties that could benefit from PFR measures to mitigate surface water flooding. Local authorities such as Falkirk, Highland and Argyll and Bute could benefit from PFR to mitigate coastal flooding. Local authorities such as Aberdeen City, Aberdeenshire, Dumfries and Galloway, Perth and Kinross and the Scottish Borders could benefit most from PFR to protect against fluvial flooding.
- Glasgow and other cities such as Edinburgh and Dundee benefit most from PFR measures that mitigate surface water flooding. More rural communities such as Highland and Argyll and Bute could benefit from PFR to protect against coastal flooding, and other areas such as Perth and Kinross and Highland will benefit most from fluvial flood protection,
- Present day to future (2080) increases in properties that could benefit from PFR are in the order of 30-70%, revealed by climate change analysis.

9.3 Current uptake

Qualitative analysis was base on a questionnaire to local authorities and flood groups, see appendic C. The purpose was to assess the uptake of PFR measures across Scotland. Key conclusions are as follows:

- Between 1,400 and 1,500 properties are currently protected by PFR across Scotland.
- The number of properties with PFR measures has increased by at least 300 since 2014. The majority of this increase is due to local authority schemes.
- The majority of PFR has been implemented by the relatively few local authorities who have developed PFR subsidy schemes.
- Post-installation surveys for property owners are provided by a range of bodies, including local authorities and Scottish Flood Forum (SFF).
- Further work is needed to ensure that appropriate subcontractors are used to install PFR measures and to check that end users know how to install and use the measures.

9.4 Discussion

Our research provides a baseline assessment for PFR uptake across Scotland, supporting the Scottish Government's Living with Flooding: action plan[6]. With increasing flood risk to many communities as a result of climate change, the potential of PFR for many properties is becoming increasingly important.

The findings suggest there has been a relatively low level of uptake of PFR in Scotland in general and since the last review by the Scottish Government in 2014. The potential for wider uptake is significant. Responsible authorities are currently underperforming in terms of the use of PFR to mitigate flood risk and reduce the number of properties currently at risk. It should be noted however, that local authorities and SEPA have been working on a large number of flood studies to identify the best approach to mitigating flood risk and these are currently being reviewed by SEPA. It is anticipated that some of these will have suggested that PFR is a cost effective and priority approach in many communities and that action is planned or proposed to implement PFR.

The findings also show there is considerable potential for wider delivery of PFR, providing a significant contribution to flood risk management in Scotland. Furthermore, as the number of properties at risk of flooding in Scotland increases with climate change, PFR approaches can assist as a resilience measure against climate change and rising flood risks, particularly for those properties flooding most frequently.

Whilst current uptake is low, the level of uptake needs to increase significantly over the short to medium term to ensure that Scotland manages both current and future climate change flood risks. The uptake of PFR in Scotland would need to increase by 400-600 properties per annum to keep up with the projected increase in climate change, even without reducing current risks. This highlights both the significant role that PFR can play in managing the impacts of climate change on flood risk, but also the significant challenge in increasing uptake.

The above analysis considers the total potential benefit of PFR in Scotland but does not consider how this can be implemented, funded or procured. It also does not consider how many

[6] https://www.gov.scot/binaries/content/documents/govscot/publications/strategy-plan/2019/11/living-flooding-action-plan-delivering-property-flood-resilience-scotland/documents/living-flooding-action-plan-delivering-property-flood-resilience-scotland/living-flooding-action-plan-delivering-property-flood-resilience-scotland/govscot%3Adocument/living-flooding-action-plan-delivering-property-flood-resilience-scotland.pdf

of the above may be protected by ongoing flood protection schemes (FPS) (currently under development) or proposed for future schemes by local authorities. It should be noted that current scheme delivery is much slower than anticipated and so communities programmed to have FPS could seek PFR as a stop gap or a more achievable solution.

This baseline report provides the first step in understanding the potential for PFR in Scotland. The next stage of the Living with Flooding: action plan, is to consider reasons for the poor uptake and approaches to encourage PFR uptake more widely.

Additional steps should be undertaken to consider where to focus the delivery of PFR, how cost effective it is, how to fund this and how many of the above properties may not require PFR due to ongoing FPS works. Some of these questions will be answered by the current flood scheme prioritisation process being undertaken by SEPA and other tasks under development by the Scottish Government's PFR Delivery Group.

10 Glossary

10.1 Definitions

Property Flood Resilience (PFR) – The term which covers practical measures being installed in a property to make it more resilient to flooding. This can be provided to property owners and professional partners alike and may be installed, for example, by an individual, or by a local government as part of a flood protection scheme or PFR subsidy scheme. PFR measures are designed to improve the resilience of properties to flooding, and the emotional impacts of flooding to people. They can either prevent water from entering a property (resistance measure), for example, flood guards across doorways, or limit the damage once water has entered a property (resilience measure), for example by water-proofing the brickwork.[1]

Automatic resistance measure – Measures which keep water out of a property and are deployed automatically.

Manual resistance measure – Measures which keep water out of a property and are deployed manually (i.e. they require to be fitted by hand prior to flooding).

Resilience measure – Measures which act in a way to make a property more resilient to flood water, once water has entered a property.

Fluvial flooding – Flooding which originates from rivers.

Coastal flooding – Flooding which originates from the sea as a result of increased sea levels, tides, or swell waves (caused by wind during a storm).

Surface water flooding – Flooding which is caused by the accumulation of surface water due to runoff from topographic highs (mountains, hills), blocked drains, or other regions where water cannot soak into the ground and becomes pooled.

Groundwater flooding – Flooding caused when groundwater exceeds its normal levels or flow and as a result of this, water emerges at the ground surface (away from river channels).

PFR subsidy scheme – Schemes set out by local authorities to encourage local residents to take up PFR measures for their home. These schemes work by offering residents lower prices on a variety of PFR measures in order to encourage uptake.

Flood Protection Scheme (FPS) – FPS are schemes designed to reduce flood risk to a specific area e.g. Jedburgh FPS, Water of Leith FPS. These are generally put in place to reduce flood risk to properties, businesses and other assets at risk of flooding.

Potentially Vulnerable Area (PVA) – An area, designated by SEPA, currently under substantial flood risk and is likely to be in the future. FPS and PFR are likely to be prioritised in these areas.

10.2 PFR Measures

10.2.1 Manual resistance measures

Measure	Description
Door guard/ protection	Provides a temporary barrier to flood water at property threshold
Window guard/ protection	Provides a temporary barrier to flood water at window level
Airbrick cover	Fitted by hand to prevent water ingress via airbricks

10.2.2 Automatic resistance measures

Measure	Description
Sump and pump	Permanent installation with a separate manhole and draws flood water out from underneath the property
Non-return valve	Prevents water backing up through waste/ foul/ sewerage system
Automatic airbrick	Prevents water ingress via airbricks
General - External waterproofing, sealant etc.	Makes property walls more resistant to seepage

10.2.3 Resilience measures

Measure	Description
Replace sand-cement screeds on solid concrete slabs	Increases resistance of floor to flood water
Replace chipboard flooring with treated timber floorboards	Increases resistance of floor to flood water
Replace floor including joints with treated timber to make it water resistant	Increases resistance of floor to flood water
Replace timber floors with solid concrete	Increases resistance of floor to flood water
Tiled floors with waterpoof adhesive and grout	Increases resistance of floor to flood water
Replace insulation within walls	Increases resistance of walls to water
Replace gypsum plaster with water resistant material, such as lime plaster	Increases resistance of walls to water
Install chemical damp-proof course below joist level	Increases resistance of walls to water
Replace doors, windows, frames with water-resistant alternatives	Increases resistance of walls to water
Mount boilers on wall/move to upper floors	Decreases likelihood of flood water damage to boiler
Replace ovens with raised, built-under type	Decreases likelihood of flood water damage to oven
White goods on raised plinths or moved to first floor	Decreases likelihood of flood water damage to white goods
Move electrics and sockets well above likely flood level	Decreases likelihood of flood water damage to electrics
Move service meters well above likely flood level	Decreases likelihood of flood water damage to service meters
Separate electric circuits for upper and lower floors	If one electric circuit is damaged by flood water, the other circuit will continue to operate
Replace chipboard kitchen/bathroom units with plastic units	Increases resistance of units to flood water
Resilient plaster OR plasterboard laid horizontally	Increases resilience of walls to flood water
Lightweight doors with rising butt hinges	Allows removal of doors to prevent damage by flood water
Bottom steps made of concrete with removable carpet	Allows easy drying of steps if damaged by flood water
Removable fixtures and fittings (applicable for commercial properties only)	Allows fixtures to be removed to dry out/ repair flood damages

10.3 Data

SEPA's National Flood Risk Assessment (NFRA) – SEPA holds receptor data on all properties across Scotland including property type, flood depth and flood damages. This was the main source of data for this project's analysis. The data used was NFRA data from the 2018 assessment. The NFRA provided data on flooding from fluvial (rivers), coastal and surface water flood risk.

Flood Hazard Research Centre (FHRC) Multi-Coloured Manual (MCM) Code – FHRC have produced guidance on methods and data for flood risk management used for practical assessment of schemes and policies, known as the MCM Handbook. The MCM Code relates to the 'type' of non-residential property i.e. retail, public house, hotel. Each code relates to a different property type, making it easy to exclude property types from analysis.

10.4 Guidance

Scottish Government's Blueprint Guidance – Refers to the JBA (2014) report written as a PFR 'blueprint' for the Scottish Government. The 2014 report uses a similar methodology to this report and outlines the best practice that should be followed by local authorities when considering PFR schemes.

Scottish Government's Living with Flooding - action plan – Refers to the Scottish Government's action plan developed for delivering PFR in Scotland including building a better evidence base for PFR, influencing policy and providing clear guidance and encouraging the uptake of PFR measures. This research will support the delivery of the action plan.

CIRIA Code of Practice (CoP) – The CoP outlines six standards that PFR measures must adhere to during the PFR delivery process including assessment and surveys, commissioning, options appraisal, delivery and maintenance. This guidance should be followed by any local authorities wishing to implement PFR schemes or any other relevant stakeholders.

HM Treasury Green Book – Guidance set out by the government to inform evidence-based appraisal and decision-making of proposals. Discount rates for economic assessments can be found in here.

10.5 Flood events

Return period – The probability of a flood occurring in any given year, for example, a 200-year flood has a 0.5% change of occurring in any year. This does not mean that the flood will only occur once every 200 years.

Annual Exceedance Probability (AP) – The return period expressed as a percentage probability e.g. 0.5% AP.

10.5.1 Table of return periods

Return period (years)	5	10	30	50	100	200	1000
AP (%)	20	10	3.33	2	1	0.5	0.1

Return periods are illustrated in the table above. The lower the return period, the higher the chance of that flood occurring in any given year. The 30 year and 200-year return periods were additionally used for climate change analysis.

References

Bre, 2020. Changing attitudes to property flood resilience in the UK. [online], Available at: <https://www.bregroup.com/buzz/changing-attitudes-to-property-flood-resilience-in-the-uk/> [Accessed 17 Jan 2020].

BSI, 2015. BS 85500:2015 - Flood resistant and resilient construction - guide to improving the flood performance of buildings. British Standards Institution.

BSI, 2016. PP972 - Flood Protection Products Installation Kitemark Guide. [online], Available at: <https://www.bsigroup.com/LocalFiles/en-GB/Kitemark/PP972%20-%20Flood%20Protection%20Products%20Installation%20Kitemark%20Guide.pdf> [Accessed 20 Jan 2020].

Bowker, P. 2007. Flood resistance and resilience solutions an R&D scoping study. R&D technical report. London: Defra.

CIRIA, 2019. RP1055 - Code of practice for property flood resilience. London: CIRIA.

Defra, 2014. Best Practice in Property Level Protection Systems. [PDF], Available at: <https://www.bathnes.gov.uk/sites/default/files/siteimages/defra_best_practice_in_property_level_protection_systems_-_advice_for_local_authorities_may_2014.pdf>. [Accessed 20 Jan 2020].

Flood Re, Lamond, J., Rose, C., Bhattacharya-Mis, N. & Joseph, R. 2018. Evidence review for property flood resilience - Phase 2 report. [PDF], Available at: <https://historicengland.org.uk/images-books/publications/flooding-and-historic-buildings-2ednrev/heag017-flooding-and-historic-buildings/> [Accessed 28 Jan 2020].

Penning Rowsell, E., Priest, S., Parker, P., Morris, J., Tunstall, S., Viavattene, C., Chatterton, J. & Owen, D. 2013. A Manual for Economic Appraisal, Flood and Coastal Erosion Risk Management. Flood Hazard Research Centre.

Penning Rowsell, E., Priest, S., Parker, P., Morris, J., Tunstall, S., Viavattene, C., Chatterton, J. & Owen, D. 2019. Handbook for Economic Appraisal, Flood and Coastal Erosion Risk Management. Flood Hazard Research Centre.

Green, C., Wilson, T., Masterson, T. & Boothby, N. 2006. An assessment of the additional losses associated with groundwater flooding: A report to Hampshire County Council and Winchester City Council. Enfield: Flood Hazard Research Council.

Historic England, 2015. Flooding and Historic Buildings - 2nd Edition. [pdf], Available at: <https://historicengland.org.uk/images-books/publications/flooding-and-historic-buildings-2ednrev/heag017-flooding-and-historic-buildings/> [Accessed 20 Jan 2020]

Historic Environment Scotland, 2020. Listed building and conservation area consent. [online], Available at: <https://www.historicenvironment.scot/advice-and-support/applying-for-consents/listed-building-consent-and-conservation-area-consent/listed-building-consent/> [Accessed 20 May 2020].

JBA Consulting, May, P. & Chatterton, J. 2012. Establishing the Cost Effectiveness of Property Flood Protection: FD2657 - Final report. London: Defra.

JBA Consulting, Pettit, A. 2014. Assessing the Flood Risk Management Benefits of Property Level Protection - Final report. Edinburgh: Scottish Government.

Joseph, R. D. 2014. Development of a comprehensive systematic quantification of the costs and benefits (CB) of property level flood risk adaptation measures in England. PhD, University of the West of England.

Know Your Flood Risk, 2020. A Business guide to flood resilience. [pdf], Available at: http://www.knowyourfloodrisk.co.uk/sites/default/files/FloodGuide_ForBusinesses.pdf. [Accessed 28 Jan 2020].

National Resources Wales, 2019. Flood Risk Assessment Wales Project Report. Project Report. August 2019.

Royal Haskoning, 2012. Assessing the Economic Case for Property Level Measures in England - Final Report. Peterborough: Committee on Climate Change.

Scottish Government, 2011. Exploring the Causes and Potential Extent of Groundwater Flooding in Scotland - Scoping and Screening Study. Commission Number: CR/2008/35. Final Report, March 2011.

SEPA, 2018a. National Flood Risk Assessment. [online], Available at: <https://www.sepa.org.uk/data-visualisation/nfra2018/> [Accessed 28 Jan 2020].

SEPA, 2018b. 2018. Publication of NFRA and PVAs – FAQ. [online], Available at: <https://www.sepa.org.uk/media/399172/nfra-faq.pdf> [Accessed 27 April 2020].

11 Annex A – Criteria Assessment

11.1Flood depths

The depth at which PFR measures are deemed to be effective is generally assumed to be up to 0.6m due to the structural integrity of the building. However, there is a lack of empirical research on structural stability and testing at different flood depths, and the influence of different property construction types. This upper limit is particularly the case for resistance measures that aim to keep flood waters out of a property. An upper limit may not be applicable for resilience measures, although often there will be a practical limit in terms of how far electrical sockets or kitchen white goods can be raised, for example.

BRE (2020) states that some surveyors may suggest a limit of 0.3m to reduce the hydrostatic head generated by pressure differences on either side of the resistance measure. The British Standards Institution guidance (BSI, 2015) recommends that water can be excluded up to 0.3m, partially excluded up to 0.6m, but for flood depths above 0.6m water should be allowed to breach the property to protect structural integrity (Flood Re, 2018). The previous standard kitemarked product testing experimentally tested to a maximum flood depth of 0.9m (Defra, 2014). Additionally, the Flood Protection Products Installation Kitemark Guide - PP972 (BSI, 2016) suggests that flood protection installation surveys must be carried out before installation by a competent operative (BSI, 2016). Even though products bearing the BSI PAS1188 kitemark (now superseded by BS 851188) are tested to a depth of 0.9m, this does not mean that they should be used to that depth, in order to remain in accordance with the above standards. While in some situations, property construction would allow protection to a height of 0.9m, structural considerations must always be assessed and a more conservative 0.6m protection height has been adopted as standard practice.

Notwithstanding the above, the BS 851188 has removed the designated maximum water depth to allow products that are capable of meeting greater design depths to be tested where testing facilities exist.

CIRIA (2019) code of practice (CoP) sets out guidance for PFR which provides a single-source information point to set a benchmark for PFR. The CoP sets standards which include the following six 'stages'; 1) Hazard assessment, 2) Property survey, 3) Options development, 4) Construction, 5) Commissioning and handover, and 6) Operation and maintenance. The CoP does not state any specific depths to use for resistance/ resilience but outlines the procedures to follow when undertaking any of the aforementioned 'stages'. Further forthcoming guidance associated with the CoP may provide further evidence.

A number of research reports have considered the importance of flood depth on the selection, and cost effectiveness, of PFR measures. We have reviewed the following key papers:

1) a JBA (2012) report for Defra on the cost effectiveness of PFR;
2) a report by Royal Haskoning (2012) for the Adaptation Sub-Committee (ASC) on climate change;
3) a thesis by Joseph (2014) on systematic quantification of cost benefits of PFR;
4) a document produced by FloodRe (2018) which includes a review of the former three documents’, and
5) a JBA report for the Scottish Government (2014) assessing the flood risk management benefits of PFR.

The previous JBA (2012) report, Haskoning and Joseph all quote a value of 0.6m for resistance measures as this is accepted as the industry standard. These values are applicable to both automatic and manual resistance measures. Royal Haskoning (2012) explored the raising of resistance measures from 0.6 to 0.9m.

JBA (2014)'s technical summary stated that although some of the resistance products may provide protection up to 0.9m (as tested by the BSI kitemark scheme), a value of 0.6m was used for the analysis, apart from synthetic bags which only tend to provide protection up to 0.3m.

Flood Re adopt the general consensus that resistance measures are effective below depths of 0.6m, with the 'Water Exclusion Strategy' being implemented below depths of 0.3 m (Flood Re, 2018). This strategy involves attempting to keep all water out of a property by using materials and measures with low permeability.

There does not appear to be any readily available research discussing an upper limit for resilience measures. Most of the studies listed above either do not make the distinction between resistance and resilience measures or assume the same. Whilst one might assume that there is no limit to the depth at which resilience measures can operate to, in practice there may well be a limit to the depth at which a property can be made resilient to water ingress. For example, kitchen appliances cannot realistically be raised more than 0.6-1m from the ground. The same is also the case for electrics and sockets. In many cases resilient measures will be applied at a level that is practical and there may be a 'sliding scale' of resilience benefits. Frequent shallow floods cause little or no damage from water ingress, but less frequent, deeper floods cause gradually more damage – although still vastly less than if no PFR measures were implemented at all.

On this basis it seems practical to suggest that no depth criteria are applied to the selection of properties using resilience measures, as there will be some benefit for all flood depths and these criteria would not preclude any particular property from installing PFR resilience measures. Where flood levels are predicted to be greater than 0.6m, or exceed structural integrity, then advice relating to continued occupancy should be considered.

Application of criteria
Based on the literature review we use a value of **0.6m** as the upper limit for **resistance measures**. **No depth criteria** were used for **resilience measures** as all properties could benefit from the application, albeit with a reduced benefit for greater flood depths.

11.2Flood frequency and costs

Understanding the relevance of flood frequency to PFR measures is important for assessing the uptake, as PFR measures are not necessarily cost beneficial for properties that flood infrequently (the exception being properties that are factored into a wider flood protection scheme to manage residual risks). There have been a number of important research studies assessing the cost effectiveness of PFR, and more recent research since the last assessment undertaken for the Scottish Government. The impact of flood frequency on the cost effectiveness of PFR has been researched by JBA (2012) for Defra; Royal Haskoning (2012); and Joseph (2014). The JBA (2014) review for the Scottish Government used the JBA (2012) conclusions. The Flood Re (2018) report reviewed all the above and highlighted that Joseph's thesis suggested significantly different cost-effective frequency values compared to the previous analysis by JBA and Haskoning.

Table 7 presents a summary of the key research papers findings in terms of return period thresholds that resistance and resilience measures cease to be cost beneficial. The analysis has generally been presented in terms of manual resistance, automatic resistance, and resilience. Automatic barriers have a higher cost and therefore are not generally as cost beneficial as manual measures. Manual resistance shows the least variation in frequencies between research papers, but for automatic resistance, there is a significant difference in frequencies predicted by the JBA/Haskoning research and that undertaken by Joseph.

Table 7: Summary of return period thresholds for cost beneficial installation of resistance measures

Resistance type	Report	Return period cut off for cost beneficial installation (years) in detached/terraced properties
Manual (requires deployment prior to the flood by the owner/tenant)	JBA (2012)	50
	Haskoning (2012)	40
	Joseph (2014)	50
Automatic (will automatically operate when flood waters reach a certain level)	JBA (2012)	20/25
	Haskoning (2012)	20/25
	Joseph (2014)	50
Resilience with/without floor	JBA (2012)	5
	Haskoning (2012)	10
	Joseph (2014)	40/50

Joseph (2014) studied of the cost effectiveness of PFR is the most recent update on the financial viability of PFR in the UK and generated significantly different results to the previous analysis by JBA and Haskoning (for the CCC).

There are three key differences between this research and the previous analyses:

1) Joseph used a different discount rate to that typically used for economic assessments in the UK and recommended by HM Treasury Green Book guidance. Joseph (2014) used an 8% discount rate rather than the standard 3.5% discount rate recommended by the Treasury Green Book. The reasoning for this is not clear, but the impact is that flood benefits in this model will be lower, thus reducing the overall cost effectiveness of PFR when compared with the previous assessments (JBA, 2011 and CCC, 2010).

2) Joseph researched the intangible aspects of flooding (indirect consequences of flooding such as the impacts on wellbeing and mental health and the loss of memorabilia etc.) and incorporated a revised assessment of these into the benefits of PFR. A focus of Joseph (2014)'s PhD was to review and reassess intangible aspects of flooding. Intangible aspects of flooding were considered in the JBA and CCC study through the inclusion of stress and other mental health issues, both using a value of £2,513 per household per event. This value is substantially higher than the current recommendation for flood studies from Penning-Rowsell et.al. (2019) that suggests a much lower value in the region of £290 per household per event. Joseph goes into more detail on the intangible aspects of flooding and estimated a mean WTP value of £653 per household per year. The benefits of PFR will be more worthwhile if these psychological effects are taken into account than if they were not; although as Joseph (2014) used a lower value the difference in frequency values cannot be explained by this difference. The Environment Agency is currently carrying out additional research into the health and wellbeing aspects of flooding which is likely to show that these flood losses are much greater than previously thought, but still less than the £2,513 value used by JBA and Haskoning. Whilst this research has not yet been published, the findings are likely to make PFR schemes more cost effective for lower frequency floods.

3) Joseph considered a financial perspective rather than an economic one, as is standard for economic benefit-cost comparisons in the UK flood industry. Joseph (2014) used a financial perspective rather than the economic one. The reason for selecting this approach was that the research was starting from the point of view of the homeowner and their decision-making considerations; based on total financial costs and their disposable income. This personal point of view is valid in this instance but differs from the standard economic approach usually applied to the benefit-cost considerations used within the UK flood industry and applying Treasury Green Book principals. This financial perspective will have inflated the overall flood benefits when compared with the previous

assessments and is the primary reason why the cost effectiveness of PFR is shown to be higher than those studies that applied economic principles (for example a financial assessment includes for VAT thus generating a 20% variance in this aspect alone).

Other factors, including the differences in how damages were calculated, also influenced differences in results. Both JBA and Haskoning use the Flood Hazard Research Centres (FHRC) WAAD (Weighted Average Annual Damages) (Penning Rowsell et.al., 2013) method to calculate damages which estimates flood depths, whereas Joseph assessed flood depths for specific return periods.

The above research shows that assumptions regarding the economic calculations of flood losses, the costs of PFR measures and the calculation methods can all vary the cost effectiveness of PFR. However, the JBA (2012) and Haskoning (2012) approaches follow best practice economic principles and were therefore used in this assessment.

Application of criteria
The calculation of properties that most benefit from PFR were limited to those at risk of more frequent flood events: **Resistance (manual)** - applied to properties at risk up to the 50-year return periods **Resistance (automatic)** - applied to properties at risk up to the 30-year return periods **Resilience** - applied to properties at risk up to the 10-year return periods

11.3Other factors

There were a variety of other factors to consider when assessing the applicability of PFR to a property. These are discussed further below.

11.3.1 Groundwater flooding

Groundwater flooding, caused by the water table rising (Joseph, 2014), may impact properties which are located in areas susceptible to groundwater and have basements. It is worth noting the distinction between rising groundwater tables and locally saturated ground under hydrostatic pressure trying to rise and re-equilibrate with elevated water levels on the outside of a property.

Properties that would not be applicable for PFR can be classified by those that are at high risk of groundwater flooding and those with basements or flooring that is not resistant to rising water tables. However, classification of properties in this way would have not precluded those properties where this applies, as measures may be available to limit the ingress of water. Measures that may be applicable include basement waterproofing, water resistant flooring and the installation of a sump pump, for example.

In terms of data to support such an analysis, national groundwater risk mapping was available from Scottish Government (2011), although this only highlighted areas where groundwater could influence the duration and extent of flooding from other sources, rather than showing areas where groundwater alone could cause flooding. The presence of basements were registered in SEPA's property database within the 'Floor Level' field.

Whilst some data exists, we did not apply this rule to preclude properties from the analysis. This is primarily due to the need to assess all necessary measures when considering PFR needs on a property by property basis. Furthermore, the lack of sufficient granularity of current groundwater mapping that is available limited a sufficiently robust method to select properties on this basis.

Application of criteria
Presence of groundwater hazard is an indicator both of groundwater flooding and permeable substrate which may make resistance measures more difficult. A property survey should identify all measures needed to make a property resistant or resilient to flood risk. Groundwater was **not** applied as a rule when considering which properties may benefit most from PFR.

11.3.2 Speed of onset

The speed of flood onset is useful as it provides an indication of potential flood warning and time for deployment. In areas where there is no specific flood warning (other than SEPA flood alerts or Met Office Severe Weather Warnings) and a rapid flood onset, manual measures may not be appropriate and automatic measures may be essential (JBA, 2014). Well-developed community and individual emergency plans could have assisted here but were deemed insufficiently reliable.

Furthermore, manual measures should not be recommended to areas where speed of onset is rapid and no flood warning is available. The success rate would be significantly reduced unless local systems are in place to rapidly warn the community of rising river levels or the onset of extreme rainfall. Thus, rapid onset of flooding is not, on its own, sufficient to preclude it from the assessment of properties that might benefit from PFR.

In terms of data, SEPA owns a ‘time-to-peak’ map for primary watercourses; and this could have been used to apply an indicator of rapid onset of flooding to properties. To take into account the speed of onset, though, would have required hydrological information including the catchment lag times, which is not currently available from SEPA.

The impact of the speed of onset is dependent on the time taken to deploy a manual measure (specific to each measure), therefore the assumption would have been that properties more at risk are ones with a high speed of onset and longer deployment times. Since this was too difficult to assess at a national scale, it is down to the surveyor to identify and recommend. Furthermore, SEPA are working to improve surface flood warning so many more properties will get notification of flooding.

Application of criteria
Rapid onset of flooding should not preclude a property from benefitting from PFR, although it may increase the costs due to the need for automatic measures. A property survey should identify the most appropriate measures needed to make a property resistant or resilient to flood risk. Furthermore, local authorities may be able to provide bespoke warning systems outside SEPA's flood warning remit. Onset of flooding was therefore **not** applied as a rule when considering which properties may benefit most from PFR

11.3.3 Velocity of flooding

Flood velocity impacts PFR measures as hydrodynamic forces can sometimes cause structural issues at lower depths than the BSI recommendation (Flood Re, 2018). Green et al. (2006) state that high flow velocities can cause additional damages in addition to those caused by high flood depths.

To consider flood velocities, we would have had to exclude properties in flood risk areas where modelled velocities are predicted to exceed a predefined threshold. This threshold was not defined as far as we are aware. Furthermore, whilst flood velocities are available for some flood sources, velocities that are likely to cause structural damage are likely to be due to local conditions, temporary obstructions that divert flows and increase flow velocities locally (Green et al., 2006); both of which were not present or predictable by national flood mapping. Very high velocities are also only likely to occur in relatively extreme events, beyond what PFR measures are typically designed for.

Application of criteria
High velocities should not preclude a property from benefitting from PFR, although it may increase the costs. Whilst information on velocities were available from SEPA, the scale of mapping available was considered too coarse to reliably apply to the selection of properties and no defined limit of velocity is available to apply routinely. Furthermore, high velocities likely to limit the use of PFR are only likely to occur rarely. Velocity was **not** applied as a rule when considering which properties may benefit most from PFR.

11.3.4 Duration of flooding

Flood duration is a major factor associated with property flood losses. This is due to the fact that the UK properties are typically made of porous solid materials, such as bricks, blocks and concrete (Green et al., 2006). The longer the floodwater remains in contact with the fabric of a building, the greater the amount of floodwater absorbed by the building materials and the more extensive the damage.

Research (Green et al., 2006; Haskoning et al., 2012; Joseph et al., 2014) shows that PFR measures are more effective in areas where flooding is shallow and has a short duration. Haskoning et al. (2012) provides an in-depth analysis of flood duration, building fabric and the benefits of PFR, coming to the same conclusion that PFR measures are less effective for long duration (>12 hrs) floods.

In order to take into consideration flood duration, we would have needed an estimate of flood duration or a national map of indicative durations. Whilst current mapping methodologies are capable of providing this for fluvial flood risk (NRW, 2019), SEPA have yet to undertake this type of analysis for their national mapping. Other methods may have been available but would require bespoke analysis that was outside the scope of this assessment.

Therefore, whilst long duration flooding could have been applied as a rule to exclude properties that most benefit from PFR, the level of information readily available at a national scale was not currently available in Scotland. We have therefore not used flood duration as criteria to exclude properties from the analysis.

Application of criteria
Flood duration should not preclude a property from benefitting from PFR, although it may increase the costs due to the need for additional repair works following a flood or the installation of more resilience measures. A property survey should identify the most appropriate measures needed to make a property resistant or resilient to flood risk.

Flood duration was therefore **not** applied as a rule when considering which properties may benefit most from PFR. It is recommended that SEPA consider flood duration mapping as part of future national mapping outputs.

11.3.5 Property type

Property type was another important factor to consider; terraced properties and buildings which are attached may require their neighbour to use the same PFR measures in order for them to be effective. There is a variety of research into property type influence on PFR (Haskoning et al, 2012; JBA 2014; Joseph 2014) which suggests that different property types and floor construction methods require different costs of resistance and resilience measures.

The above research suggests that bungalows and detached houses are the most suitable for resistance measures. Terraced and connected buildings are also suitable if common ground can be agreed between neighbours (Joseph, 2014). Gaining agreement may not be an issue in instances where flooding has occurred and good practice engagement with the community is followed, but may be more difficult in cases where flooding has not occurred recently, and a more proactive application is being implemented. However, most research is currently carried out in England and Wales, where PFR is usually installed as part of a scheme as opposed to the responsibility being on the property owner.

Property 'type' was included within SEPA's property and NFRA dataset, therefore this factor could have been taken into account. However, the exclusion of terraced properties was not applied as this alone should not preclude properties from obtaining PFR if best practice guidance and good engagement with the community is followed.

Application of criteria

Property type, specifically terraced or connected buildings should not preclude a property from benefitting from PFR, although careful engagement and communication is required when dealing with these properties.

Property type was therefore **not** applied as a rule when considering which properties may benefit most from PFR.

11.3.6 Historic status

The historic status of a building may constrain the type of PFR measures that can be used (Flood Re, 2018). Historic England (2015) published a report outlining how flooding may affect historic buildings. This report notes that older buildings behave differently to modern ones (e.g. they may be built with more permeable materials like timber, lime mortars and plasters and soft bricks), they therefore may be less applicable to resilience measures due to the longer period of drying out that is required. In addition, some PFR measures may require listed building consent, especially those that involve alteration of the interior or exterior of the building (Historic Environment Scotland, 2020). Planning consent for buildings within a conservation area may also be required.

National datasets on listed building status were available, but they are not georeferenced and could not readily be tagged against SEPA's national property database. Therefore, when assessing those properties that most benefit from PFR, the exclusion of listed buildings may have been applicable as the presence of listed status or location within a conservation area should not preclude a property from gaining PFR. For this reason and the fact that no readily available database on listed status was available in a suitable format for this study, we excluded this aspect from the analysis. National datasets on building listed status and SEPA's property database could be combined in the future to help identify properties cultural status that may influence the ability of PFR measures to be installed.

Application of criteria
Historic status of a property should not preclude a property from benefitting from PFR, although careful consideration of appropriate PFR measures would have been needed as well as engagement with local planning authority and conservation officers. Historic status was **not** applied as a rule when considering which properties may benefit most from PFR. This could be considered as a sensitivity test in the future if listed building status could be readily combined with SEPA's property database. It is recommended that an investigation is made to determine if the two databases mentioned could be combined.

11.3.7 Number of occupants

The number of occupants in a building may influence the choice and effectiveness of PFR measures (Flood Re, 2018). For example, if a large manual barrier which requires two people to deploy efficiently (and in a timely manner) is provided to a property with a single resident, the barrier would take longer to deploy (or with higher risk of failure) and therefore it may not be suitable for that property.

Best practice and a suitable survey should however only recommend measures that are suitable for both the property and resident. Thus, single occupancy should not preclude properties from benefitting from PFR, if carried out in a way that follows best practice.

There is little research into this factor and in order to assess it information on occupancy would have been needed; and whilst this may have been available from Census data, they were not at a sufficiently granular level to apply at the property level. We therefore omitted this from the assessment.

Application of criteria
Sole occupancy of a property should not preclude a property from benefitting from PFR, although careful consideration of appropriate PFR measures is needed and may increase the overall costs as more passive systems may be required. Sole occupancy was therefore **not** applied as a rule when considering which properties may benefit most from PFR

11.3.8 Non-standard construction/poorly maintained structures

Properties or buildings with non-standard construction, poor quality brick, porous material or poorly maintained structures can all influence the uptake of PFR measures. Approaches which require covering of openings may not operate correctly if the building material is poor (Flood Re, 2018). It was therefore assumed that properties with poor construction standards should use resilience measures as opposed to resistance.

This factor is very property specific, however, and other measures may be applicable to counter porous materials or non-standard construction. Furthermore, there was no readily available national dataset to inform this assessment.

Application of criteria

Non-standard construction or poorly maintained structures is of key concern to a surveyor when considering PFR measures, but was impossible to apply as criteria for the assessment of properties that most benefit from PFR due to the lack of any suitable data on this aspect at a national scale. Non-standard construction was therefore **not** applied as a rule when considering which properties may benefit most from PFR.

11.3.9 Flood warning systems

Good and timely flood warning reduces damages to all property by giving residents time to respond. The presence of flood warning systems is needed when using resistance measures that require manual implementation (those that are not passive or automatic). Sufficient flood warning with amply lead times is required to give residents time to deploy manual systems. Defra (2014) state that consideration of flood warning systems must be taken into account when installing manual measures. Flood warnings are beneficial to minimise the probability of failure of manual resistant PFR systems, as it allows property owners sufficient time to deploy the measures. Joseph (2014) also concluded that flood warning systems had the ability to reduce intangible impacts of flooding through the use of PFR measures.

The assumption for this component was therefore that manual measures can only be installed in areas where flood warning systems are present. However, whilst flooding warning is generally good practice for manual measures, areas applicable for manual resistance measures can still be identified, with flood warnings considered as a future sensitivity analysis. Flood warning systems should not preclude a property from benefitting from manual resistance measures.

A Resistance (manual) iteration with flood warnings embedded into the analysis would allow areas suitable for manual measures to be identified as an output, since flood warnings are recommended for areas where manual measures are in place (JBA, 2014). These results would be indicative of areas where manual resistance measures would be suitable, coupled with flood warning systems.

Whilst SEPA keep a GIS layer that shows areas covered by flood warning systems, the lack of flood warning should not preclude properties at risk from benefitting from PFR. Furthermore, SEPA is investing in its direct rainfall forecasting. This could benefit those areas at risk from surface water flooding in the future.

Application of criteria
The presence of flood warning should be considered good practice when using manual resistant PFR measures but should not preclude a property from benefitting from PFR as automatic or resilience measures should be recommended in areas of rapid onset, surface water flood risk and where flood warning is unlikely to be provided in the future. Flood warning was therefore **not** applied as a rule when considering which properties may benefit most from PFR as other non-SEPA flood warning approaches can be implemented by a LA or a local flood group. SEPA and the Met Office issue flood alerts and extreme weather warnings, therefore the removal of areas where flood warning is not applicable would miss important areas of flood risk from surface water that could benefit from PFR. Flood warning is suggested for future analysis as a sensitivity test to apply to resistant manual measures only and was therefore **excluded** from analysis.

11.3.10 Commercial buildings

A building's commercial status does not preclude it from PFR measures, although slightly different measures may apply to these buildings. Some property types may also not be applicable to the standard type of PFR measures used for residential properties; warehousing and industrial properties, for example.

Know Your Flood Risk (2020) compiled a report for businesses wishing to use PFR. These included similar resistance and resilience measures to residential buildings including sump pump, flood resistant doors, raising appliances and moving vehicles to higher ground. However, careful consideration of appropriate measures is required and may include more expensive measures due to the number and width of openings for example.

Based on evidence of PFR implementation from the rest of the UK, PFR is most likely to be applied to retail, office and public buildings rather than warehousing and industrial. Whilst these latter property types are not precluded from the application of PFR measures, the type of measures needs careful consideration and the use of bespoke measures are more likely. They are therefore less likely to be property types 'most' benefitting from PFR. We therefore recommend that only retail, office and public buildings are used within our analysis.

SEPA's property database includes the Flood Hazard Research Centre Multi-Coloured Manual (MCM) (Penning-Rowsell et al., 2013) code which identifies these property types (code 2, 3 and 6 for retail, office and public buildings respectively). This data will be used to extract the properties that most benefit.

The other factor to include is the area of the property, on the basis that very large properties may not benefit most from PFR due to the need for bespoke measures or costly PFR measures. There is little research on this aspect and no evidence on the specific threshold to apply. The FHRC MCM provides information on average property areas for different property types which could be used as a proxy for omitting larger property types. We therefore used MCM code 'indicative areas' to omit overly large commercial properties from the analysis.

Application of criteria
PFR is best suited to typical 'high street' commercial property types that may be included within a community PFR scheme. Isolated or larger warehousing and industrial properties are not precluded from obtaining PFR measures but are likely to require most costly and bespoke types of measures. For this reason, we recommend that only retail, office and public buildings are included in the analysis and only those that have an area below the MCM indicative area for each type. This will be carried out by utilising the MCM 'indicative area' to omit overly large commercial properties from the analysis. This is perhaps an academic argument; larger properties may be very susceptible to flood risk and be better able to afford PFR. However, the above recommendations are made in relation to this national level assessment and the requirement to assess properties that 'most benefit' from PFR. It should not, however, be used to preclude properties when assessing PFR schemes at a local level. Commercial buildings were therefore **included** in the analysis to identify properties that would benefit most from PFR. However, some restrictions have been applied.

11.3.11 Clustering of properties

Clustered properties are more likely to be identified and progressed as a PFR scheme than standalone ones. JBA (2014) explored the impact of clustered properties on PFR measures, stating that this should be considered as a potential technical opportunity or constraint. Of course, isolated properties would still benefit from PFR but implementation of this is more likely to be reliant on a proactive approach by the homeowner rather than a scheme implemented by the local authority, housing association or other organisation. This approach may also be more appropriate to resilience.

This assumption perhaps pre-empts future research on how best to encourage the uptake of PFR, but the emerging evidence from England is that PFR uptake is most likely to be in communities at risk where it can be delivered as part of a focused scheme, and incorporate training and emergency planning systems in addition to the installation of measures.

Conversely, evidence of PFR implementation in Scotland (JBA, 2014) shows that PFR subsidy schemes can be highly effective at delivering PFR to isolated properties.

GIS procedures can be used to count clustered properties within grids and analyse these. The assumption would be that properties standing alone would be less likely to uptake PFR, since there is less likely to be funding for these types of property. Despite this, clustering of properties was not applied as a criterion as at present, the responsibility of property resilience in Scotland lies mainly with the owner. Therefore, excluding isolated properties would remove many of the properties that could potentially benefit.

There is the potential for further analysis to help local authorities and other responsible authorities to prioritise PFR delivery on the back of this research. For example, cluster analysis using data on community/settlement from the NFRA could be used to identify specific areas most likely to benefit from PFR, but perhaps excluded from SEPA's national level PVA categorisation. This would allow a breakdown of properties benefitting and at risk with a view to informing targeted action for specific communities. Additionally, the analysis could be carried out at the PVA level (to focus attention at this important level of geographic category, or perhaps by social deprivation areas) to focus promotion of PFR to those most in need or least able to respond to the impacts of flooding, although this could also be examined as an outcome in its own right.

Application of criteria

If considering properties that are most likely to benefit from PFR measures, one also needs to consider the approach that PFR is undertaken. As there is guidance on this, we anticipate that it is communities at risk rather than isolated properties that will benefit from a formal PFR scheme. Whilst properties located in a community may be more likely to receive or implement a PFR scheme, isolated properties will not be precluded from PFR.

Clustering of properties was **not** applied as a rule when considering which properties may benefit most from PFR, although this technique could be used as a tool to help flood management organisations to identify potential areas at risk that may not benefit from other proactive forms of FRM.

It should be noted that at present, property resilience in Scotland lies mainly with the owner as there is not a specific process to promote resilience in the same way as in England where much of the research is based.

11.3.12 Upper floor flats

Upper floor flats will not benefit from PFR directly, except where there is direct and non-shared access to upper floor flats from ground level. Typically, damage, other than to entrance ways, is minimal for upper floor flats. Thus, the exclusion or inclusion of upper floor flats depends one's point of view and whether it is property damage or secondary impacts to the homeowners that is the criteria of assessment. This is complicated when flats have a shared responsibility for repair or legal obligations related to shared areas.

Upper floor flats were distinguished in the SEPA property dataset using the 'floor level' field so could have been removed from the analysis. SEPA's NFRA ignored upper flood flats, so the inclusion of these could have resulted in discrepancies if comparisons were made against their property counts.

12 Annex B – Quantitative Methodology

12.1Data provision

SEPA’s NFRA 2018 data was provided to JBA to undertake the analysis. The data includes every property in Scotland in one of several generic property type databases:

- Residential
- Non-residential
- Community facilities
- Agricultural buildings
- Airports
- Cultural heritage
- Utilities

Each property is recorded with a geographical point and is attributed with a number of address information and flood risk metrics. The key attribute data used as part of this analysis included the following:

- Flood Hazard Research Centre’s Multi-Coloured Manual (Penning-Rowsell et al., 2019) code. This determines the property type.
- Floor level. Allows upper floor flats, and properties with known basements to be removed.
- Area. Used to exclude overly large properties.
- Flood depths for each of the six nationally modelled flood events and two climate change scenarios.

SEPA’s 2011 NFRA identified half the number of properties at risk than the 2018 assessment. This is mostly attributed to advancements in flood modelling and mapping and the way properties at risk are identified, through the following means (SEPA, 2018b):

1. Improvement of the property dataset to better reflect flood risk to sites made up of separate buildings.
2. The use of building footprints as opposed to a point dataset to represent properties.
3. Improved Ordnance Survey (OS) mapping, there is a better understanding of the types of property at risk, and therefore the potential impacts.
4. The reliability and availability of receptor data has improved, including homes, businesses, transport, cultural heritage, agriculture.

SEPA’s data provides flood levels for the following flood events:

Table 8: SEPA flood events available from NFRA 2018

Return period	10yr	30yr	50yr	100yr	200yr	1000yr	30yr + climate change	200yr + climate change
Annual probability	10%	3.33%	2%	1%	0.5%	0.1%	-	-
Fluvial	✓	✓	✓	✓	✓	✓	✓	✓
Coastal	✓	✓	✓	✓	✓	✓	X	✓
Surface Water	✓	✓	✓	✓	✓	✓	✓	✓

Flood event magnitudes are described in terms of return period or annual probability. A flood event of a particular magnitude that is on average likely to occur (for example) once in every ten years is described as 10-year return period flood.

Another useful term closely linked to return period is a flood's annual probability (AP). This is the probability of a flood greater than a given magnitude occurring in any year and calculates as the inverse of the return period. For example, there is a 1 in 10 chance of a flood exceeding the 10-year flood in any one year so the AP is calculated by 1/10 giving a 10% AP for the 10-year flood event. For ease of readability, a flood event will primarily be written as a return period in years, i.e. 10-year return period event hereafter.

The data is provided at a national level but for each key flood source: fluvial, coastal and surface water.

12.2 Data exclusion

Not every part of the data provided is relevant for the scope of this study; therefore some data is excluded from the analysis. Data was provided as residential and non-residential for coastal, fluvial and surface water flooding. Properties not flooding above the 200+CC event were excluded from the data in GIS for each of these datasets. 200+CC will be the largest flood extent considered, and therefore properties which do not flood during this event will not be eligible for PFR and have been excluded.

12.3 Calculations

Calculations were performed for the following scenarios:

1. Resilience – Fluvial, coastal and surface water
2. Resistance (automatic) – Fluvial, coastal and surface water
3. Resistance (manual) – Fluvial, coastal and surface water

Calculations included analysis of depth and frequency. For residential properties, analysis was undertaken using the criteria in Table 9. For non-residential properties, there was an additional layer of analysis; all MCM codes except 2 (retail), 3 (offices) and 6 (public buildings) were excluded from calculations, and properties larger than the MCM indicative area were also excluded. Table 9 shows the criteria used for calculations and Table 10 shows the MCM codes used and the relative indicative floor areas.

Table 9: Calculation criteria for applicability of each PFR type

PFR type	Depth (m)	Frequency (years)
Resistance (manual)	<0.6	50
Resistance (automatic)	<0.6	30
Resilience	All depths	10

Table 10: MCM codes, property types and indicative floor areas for non-residential properties

MCM Code	Property Type	Floor Area (m^2)
2	Retail	340
3	Offices	360
6	Public Buildings	1,300

Once the exclusions were applied the data was analysed by local authority and subsequently flood source. The final outputs were a count of properties benefitting from PFR at risk from fluvial, surface water and coastal flooding by local authority area.

12.4 Climate change analysis

Climate change analysis of the results used SEPA NFRA 2018 values for 30+CC and 200+CC events in the following steps:

1. SEPA NFRA 2018 30+CC and 200+CC projections were plotted as a scatter graph.
2. An appropriate trendline was fitted.
3. The formula of the trendline was used to estimate risk levels for the remaining design events of interest that were not assessed by SEPA (10+CC and the 50+CC).
4. For the coastal data that is missing the 30+CC data, the uplift between the 200 year and 200+CC was used and applied to the other design events being considered. This is likely to over-estimate the climate change estimates.

12.5 Limitations

It should be noted that all the data presented are based on the assumptions outlined in Section 4 and do not account for double counting of properties at risk from multiple flood sources. Double counting has been identified as having an impact on the results, potentially over-predicting the properties benefitting nationally by up to 35,000.

13 Annex C – Questionnaire

Survey: Property Flood Resilience in Scotland

Property Flood Resilience (PFR) measures can significantly reduce the risk of flood water entering a property. PFR measures can help make a property more resilient to the physical impacts of flooding and the emotional impact to a person caused by flooding. PFR measures are often broken down into 'Resistance' and 'Resilience' measures: 1) Resistance measures aim to keep floodwater outside the property. Measures include door guards, airbrick covers, non-return valves and sump/pump for example. 2) Resilience measures limit damage caused as a result of water entering a property. This includes measures such as waterproof plaster, raised electric sockets, solid concrete floors and tiled floor coverings. Measures aims to reduce flood damage and shorten the recovery time after a flood. The Scottish Government and ClimateXChange want to assess the uptake of PFR across Scotland in order to identify areas which may benefit from PFR, and encourage more local authorities to set up PFR schemes. JBA Consulting have been commissioned to carry out a review of PFR in Scotland and this questionnaire is part of understanding PFR uptake and performance. The study includes both domestic and non-domestic properties. There are 28 questions to be completed in this questionnaire. Some may not be applicable. We anticipate that this will take 10-15 mins to complete. Privacy Notice The information collected in this questionnaire will be used as part of the Property Flood Resilience in Scotland study. Only the JBA Consulting's designated research team will have access to the questionnaire responses. The information will not be passed on to any third parties or used for any other purposes than this study. Responses are anonymous and properties will not be identifiable in any research outputs. If you would like to receive the final report please provide your email. The email addresses will be held by ClimateXChange in order to send you the final report, and will not be part of the research data. This contract is with the University of Edinburgh through ClimateXChange. You can read more about the University's data protection policy here https://www.ed.ac.uk/records-management/policy/data-protection .

Section 1- General Information

1. Are you filling this form out for one property or multiple properties? If filling out for multiple properties, please select 'other' and state the number of properties you are filling out for.

- One property
- Other (Please state)

2. What is your relationship to the property/properties?

- Owner
- Tenant
- Member of local flood group
- Member of local authority
- Housing association
- Other (Please state)

3. What is the address of the property/properties? If filling out for multiple properties in the same street, please state the street(s), the property numbers and addresses if known.

4. Is the property(s):

- Domestic
- Non-domestic

5. Has the property/properties previously flooded?

- Yes
- No
- Not sure / don't know

Section 2 – Property Flood Resilience Measures

6. Are there currently any Property Flood Resilience measures installed in the property/properties? If no, proceed to Question 18.

- Yes
- No
- Not sure / don't know

7. Are these Property Flood Resilience measures resistance or resilience?

- Resistance
- Resilience
- Combination of both
- Not sure / don't know

8. Has the property flooded since these measures were installed? If no, proceed to Question 10.

- Yes
- No
- Not sure / don't know

9. Have the Property Flood Resilience measures been found to be effective at reducing flood damage?

- Yes
- No
- Not sure / don't know

10. When were the Property Flood Resilience measures installed? If you have multiple measures, or are filling out for multiple properties, please state the date of the first installation. If you are not sure please state 'don't know'.

11. Who were the Property Flood Resilience measures installed by?

- Housing association
- Local authority
- Contractor
- DIY
- Not sure / don't know
- Other (Please state)

Section 3 – PFR Measures - Resistance

12. What type(s) of Property Flood Resilience (resistance) measures were installed?

- Door guard/protection
- Flood door
- Window guard/protection
- Airbrick cover
- Non return valve
- Sump and pump
- Other (Please state)

13. Use the space below to provide any other information on the type of resistance measures installed (if required).

Section 4 – Property Flood Resilience Measures - Resilience

14. What type(s) of resilience measures have you taken?

- Floors
- Walls
- Interiors
- Other (Please state)

15. Which floor resilience measures have you taken?

- Replace sand-cement screeds on solid concrete slabs
- Replace chipboard flooring with treated timber floorboards
- Replace floor including joints with treated timber to make it water resistant
- Replace timber floors with solid concrete
- Tiled floors with waterproof adhesive and grout
- Other (Please state)

16. Which wall resilience measures have you taken?

- Replace insulation within walls
- Replace gypsum plaster with water resistant material, such as lime plaster
- Install chemical damp-proof course below joist level
- Replace doors, windows, frames with water-resistant alternatives
- Other (Please state)

17. Which interior resilience measures have you taken?

- Mount boilers on wall/move to upper floors
- Replace ovens with raised, built-under type
- White goods on raised plinths or moved to first floor
- Move electrics and sockets well above likely flood level
- Move service meters well above likely flood level
- Separate electric circuits for upper and lower floors
- Replace chipboard kitchen/bathroom units with plastic units
- Resilient plaster OR plasterboard laid horizontally

- Lightweight doors with rising butt hinges
- Bottom steps made of concrete with removable carpet
- Removable fixtures and fittings (applicable for commercial properties only)
- Other (Please state)

18. Have you undertaken any other measures to mitigate flood risk?
    - Registering for flood warnings
    - Moved sentimental items/important documents upstairs
    - Use of sandbags or Aqua-Sacs
    - Prepared flood plan and flood kit
    - Other (Please state)

Section 5 – Costs and funding

19. What is the estimated overall cost of these measures (resistance and resilience)? If filling out for multiple properties, please state the overall cost for all properties combined.

20. Did you receive any financial contributions or discount towards the Property Flood Resilience measures? If yes, please use the 'other' option to additionally state whom you received the contributions from.
    - Yes (select this box AND other)
    - No
    - Not sure / don't know
    - Other (Please state)

Section 6 – Surveys

21. Was a survey carried out at the property/properties prior to installation?
    - Yes
    - No
    - Not sure / don't know

22. Was a survey carried out at the property/properties after installation?
    - Yes
    - No
    - Not sure / don't know

23. If you answered yes to the previous two questions, please describe the type of survey(s), date of survey(s) and who carried it/them out.

Section 7 – Maintaining Property Flood Resilience Measures

24. Do you have any warranties/maintenance agreements?
    - Yes
    - No
    - Not sure / don't know

25. Who is responsible for maintaining the measures/products?

26. Have you attended any flood emergency practice events with the local flood group or local authority?

- Yes
- No
- Not sure / don't know

Section 8 – Further information

Thank you for completing this questionnaire.

27. If you have any further comments, please provide them below.

28. If you would like to contribute to further research on PFR please provide contact details or email: scotpfr@jbaconsulting.com

14 Annex D – Tabular results of regional analysis

Table K: Number of residential (RP) and non-residential (NRP) properties that could potentially benefit from PFR resilience measures in each local authority for each flood source

	Resilience (10-year return period)									
	Number of NRP benefitting			Number of RP benefitting			Total properties benefitting			
Local Authority	**Fluvial**	**Coastal**	**Pluvial**	**Fluvial**	**Coastal**	**Pluvial**	**Fluvial**	**Coastal**	**Pluvial**	**All**
Aberdeen City	167	0	154	882	0	1159	1049	0	1313	2362
Aberdeenshire	175	34	132	1311	49	946	1486	83	1078	2647
Angus	63	20	87	381	44	638	444	64	725	1233
Argyll and Bute	212	271	109	586	276	261	798	547	370	1715
City of Edinburgh	51	21	143	453	23	1242	504	44	1385	1933
Clackmannanshire	4	0	19	88	6	499	92	6	518	616
Dumfries and Galloway	225	82	86	1253	361	742	1478	443	828	2749
Dundee City	5	13	48	68	19	420	73	32	468	573
East Ayrshire	129	0	62	498	0	495	627	0	557	1184
East Dunbartonshire	39	0	59	240	0	648	279	0	707	986
East Lothian	86	29	11	422	174	268	508	203	279	990
East Renfrewshire	27	0	38	310	0	631	337	0	669	1006
Falkirk	27	23	24	168	287	684	195	310	708	1213
Fife	110	30	139	787	231	1309	897	261	1448	2606
Glasgow City	59	16	207	1210	105	2730	1269	121	2937	4327
Highland	165	182	101	1013	681	916	1178	863	1017	3058
Inverclyde	7	8	74	113	91	565	120	99	639	858
Midlothian	5	0	25	74	0	328	79	0	353	432
Moray	36	35	64	362	138	555	398	173	619	1190
Na h-Eileanan Siar	2	64	0	77	227	0	79	291	0	370
North Ayrshire	29	27	173	413	61	1090	442	88	1263	1793
North Lanarkshire	26	0	55	158	0	775	184	0	830	1014
Orkney Islands	3	35	55	33	241	118	36	276	173	485
Perth and Kinross	115	1	47	1335	14	437	1450	15	484	1949
Renfrewshire	49	40	52	658	200	1264	707	240	1316	2263
Scottish Borders	175	16	237	1073	18	781	1248	34	1018	2300
Shetland Islands	6	9	0	12	39	0	18	48	0	66
South Ayrshire	32	12	13	697	29	272	729	41	285	1055
South Lanarkshire	63	0	49	478	0	857	541	0	906	1447
Stirling	36	1	29	362	19	280	398	20	309	727
West Dunbartonshire	57	90	114	876	571	960	933	661	1074	2668
West Lothian	4	0	41	172	0	687	176	0	728	904
Total	2189	1059	2447	16563	3904	22557	18752	4963	25004	48719

Table L: Number of residential (RP) and non-residential (NRP) properties that could potentially benefit from PFR resistance (automatic) measures in each local authority for each flood source

	Resistance (Automatic) (30-year return period)									
	Number of NRP benefitting			Number of RP benefitting			Total properties benefitting			
Local Authority	Fluvial	Coastal	Pluvial	Fluvial	Coastal	Pluvial	Fluvial	Coastal	Pluvial	All
Aberdeen City	390	0	249	2930	3	2054	3320	3	2303	5626
Aberdeenshire	234	38	172	1663	54	1397	1897	92	1569	3558
Angus	122	26	120	752	77	838	874	103	958	1935
Argyll and Bute	449	343	116	861	371	300	1310	714	416	2440
City of Edinburgh	108	22	304	1220	33	2544	1328	55	2848	4231
Clackmannanshire	29	0	23	617	8	622	646	8	645	1299
Dumfries and Galloway	306	84	121	1745	446	1056	2051	530	1177	3758
Dundee City	6	15	100	91	24	643	97	39	743	879
East Ayrshire	172	0	76	821	0	694	993	0	770	1763
East Dunbartonshire	53	0	79	430	0	1026	483	0	1105	1588
East Lothian	173	36	18	717	218	367	890	254	385	1529
East Renfrewshire	38	0	58	404	0	915	442	0	973	1415
Falkirk	31	156	45	399	2780	1024	430	2936	1069	4435
Fife	170	38	199	1252	317	1752	1422	355	1951	3728
Glasgow City	88	17	454	2317	133	5034	2405	150	5488	8043
Highland	225	214	129	1359	905	1150	1584	1119	1279	3982
Inverclyde	53	8	105	254	124	700	307	132	805	1244
Midlothian	5	0	32	85	0	403	90	0	435	525
Moray	45	36	88	453	145	700	498	181	788	1467
Na h-Eileanan Siar	2	72	0	84	243	0	86	315	0	401
North Ayrshire	69	30	203	1325	70	1439	1394	100	1642	3136
North Lanarkshire	37	0	80	295	0	1345	332	0	1425	1757
Orkney Islands	5	142	60	36	524	144	41	666	204	911
Perth and Kinross	158	3	62	1676	55	574	1834	58	636	2528
Renfrewshire	55	46	95	781	274	1817	836	320	1912	3068
Scottish Borders	391	16	251	2067	21	891	2458	37	1142	3637
Shetland Islands	6	9	0	12	39	0	18	48	0	66
South Ayrshire	39	12	33	868	61	505	907	73	538	1518
South Lanarkshire	106	0	113	778	0	1411	884	0	1524	2408
Stirling	55	1	35	670	24	386	725	25	421	1171
West Dunbartonshire	64	140	136	1074	689	1152	1138	829	1288	3255
West Lothian	11	0	57	406	0	1099	417	0	1156	1573
Total	3695	1504	3613	28442	7638	33982	32137	9142	37595	78874

Table M: Number of residential (RP) and non-residential (NRP) properties that could potentially benefit from PFR resistance (manual) measures in each local authority for each flood source

	Resistance (Manual) (50-year return period)									
	Number of NRP benefitting			Number of RP benefitting			Total properties benefitting			
Local Authority	**Fluvial**	**Coastal**	**Pluvial**	**Fluvial**	**Coastal**	**Pluvial**	**Fluvial**	**Coastal**	**Pluvial**	**All**
Aberdeen City	414	0	337	3250	3	2951	3664	3	3288	6955
Aberdeenshire	298	46	219	2038	84	1944	2336	130	2163	4629
Angus	154	26	146	834	96	1268	988	122	1414	2524
Argyll and Bute	464	394	145	914	450	448	1378	844	593	2815
City of Edinburgh	117	22	430	1288	44	3671	1405	66	4101	5572
Clackmannanshire	30	0	35	642	8	1009	672	8	1044	1724
Dumfries and Galloway	386	93	150	2089	512	1542	2475	605	1692	4772
Dundee City	7	16	134	99	32	916	106	48	1050	1204
East Ayrshire	183	0	88	1058	0	802	1241	0	890	2131
East Dunbartonshire	53	0	104	458	0	1475	511	0	1579	2090
East Lothian	192	47	45	796	250	653	988	297	698	1983
East Renfrewshire	38	0	69	415	0	1231	453	0	1300	1753
Falkirk	33	170	65	492	3098	1510	525	3268	1575	5368
Fife	181	41	273	1338	372	2627	1519	413	2900	4832
Glasgow City	101	20	673	2559	241	7268	2660	261	7941	10862
Highland	271	229	210	1576	1061	1986	1847	1290	2196	5333
Inverclyde	63	27	142	273	177	1017	336	204	1159	1699
Midlothian	5	0	51	91	0	630	96	0	681	777
Moray	52	40	131	498	151	1225	550	191	1356	2097
Na h-Eileanan Siar	2	77	0	87	257	0	89	334	0	423
North Ayrshire	84	56	215	1681	104	1708	1765	160	1923	3848
North Lanarkshire	38	0	124	321	0	1990	359	0	2114	2473
Orkney Islands	5	152	75	36	554	177	41	706	252	999
Perth and Kinross	187	6	99	1894	58	968	2081	64	1067	3212
Renfrewshire	61	52	141	895	311	2881	956	363	3022	4341
Scottish Borders	441	16	339	2306	21	1289	2747	37	1628	4412
Shetland Islands	6	9	0	13	41	0	19	50	0	69
South Ayrshire	39	14	33	952	75	517	991	89	550	1630
South Lanarkshire	135	0	151	950	0	2016	1085	0	2167	3252
Stirling	63	1	52	860	29	612	923	30	664	1617
West Dunbartonshire	76	173	205	1148	771	1769	1224	944	1974	4142
West Lothian	12	0	78	431	0	1654	443	0	1732	2175
Total	4191	1727	4959	32282	8800	49754	36473	10527	54713	101713

Table N: The number of residential (RP) and non-residential (NRP) properties at risk in each local authority for each flood source for the 200 year return period

	Number of properties at risk (200-year return period)									
	Number of NRP at risk			Number of RP at risk			Total properties at risk			
Local Authority	**Fluvial**	**Coastal**	**Pluvial**	**Fluvial**	**Coastal**	**Pluvial**	**Fluvial**	**Coastal**	**Pluvial**	**All**
Aberdeen City	337	1500	13	2951	6994	3	3288	8494	16	11798
Aberdeenshire	219	1159	167	1944	2476	84	2163	3635	251	6049
Angus	146	670	157	1268	1187	96	1414	1857	253	3524
Argyll and Bute	145	1153	812	448	1734	450	593	2887	1262	4742
City of Edinburgh	430	624	49	3671	3298	44	4101	3922	93	8116
Clackmannanshire	35	161	22	1009	1000	8	1044	1161	30	2235
Dumfries and Galloway	150	1444	329	1542	2578	512	1692	4022	841	6555
Dundee City	134	55	104	916	105	32	1050	160	136	1346
East Ayrshire	88	578	0	802	1356	0	890	1934	0	2824
East Dunbartonshire	104	195	0	1475	575	0	1579	770	0	2349
East Lothian	45	572	127	653	1327	250	698	1899	377	2974
East Renfrewshire	69	218	0	1231	548	0	1300	766	0	2066
Falkirk	65	194	1598	1510	557	3098	1575	751	4696	7022
Fife	273	873	244	2627	1908	372	2900	2781	616	6297
Glasgow City	673	944	279	7268	4692	241	7941	5636	520	14097
Highland	210	1197	603	1986	1861	1061	2196	3058	1664	6918
Inverclyde	142	250	139	1017	578	179	1159	828	318	2305
Midlothian	51	94	0	630	124	0	681	218	0	899
Moray	131	428	108	1225	543	151	1356	971	259	2586
Na h-Eileanan Siar	0	36	232	0	88	257	0	124	489	613
North Ayrshire	215	429	163	1708	2458	105	1923	2887	268	5078
North Lanarkshire	124	181	0	1990	387	0	2114	568	0	2682
Orkney Islands	75	61	592	177	41	554	252	102	1146	1500
Perth and Kinross	99	1363	58	968	2384	59	1067	3747	117	4931
Renfrewshire	141	344	338	2881	1762	311	3022	2106	649	5777
Scottish Borders	339	1726	35	1289	3568	21	1628	5294	56	6978
Shetland Islands	0	17	68	0	14	41	0	31	109	140
South Ayrshire	33	302	46	517	1197	75	550	1499	121	2170
South Lanarkshire	151	506	0	2016	1339	0	2167	1845	0	4012
Stirling	52	531	23	612	1264	29	664	1795	52	2511
West Dunbartonshire	205	258	473	1769	2006	771	1974	2264	1244	5482
West Lothian	78	125	0	1654	655	0	1732	780	0	2512
Total	4959	18188	6779	49754	50604	8804	54713	68792	15583	139088

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Scotland's centre of expertise connecting climate change research and policy

info@climatexchange.org.uk
+44(0)131 651 4783
@climatexchange_
www.climatexchange.org.uk

ClimateXChange, Edinburgh Centre for Carbon Innovation, High School Yards, Edinburgh EH1 1LZ